U.S. FISH AND WILDLIFE SERVICE
NEW ENGLAND FIELD OFFICE
SPECIAL PROJECT REPORT: FY97-MEFO-5-EC

ENVIRONMENTAL CONTAMINANTS IN FISH FROM THE NASHUA RIVER

FORT DEVENS AYER, MASSACHUSETTS

December 1997

MISSION

U.S. FISH AND WILDLIFE SERVICE

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Fort Devens
AYER, MASSACHUSETTS

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December 1997

EXECUTIVE SUMMARY

For decades, the Nashua River received environmental pollutants from non-point and point sources that included industrial entities, municipalities, and military activities. Fort Devens, a former U.S. Army installation and currently a Superfund Site, is divided by the river in Ayer, Massachusetts. In this particular section of the river, concentrations of environmental contaminants in sediments are highly elevated. Prior to this study, the status of contaminants in fish from this section of the river was unknown. In 1994, the Environmental Protection Agency provided funds to the U.S. Fish and Wildlife Service (USFWS) to conduct a screening level contaminant survey of fish in the Fort Devens section of the Nashua River.

Between August 9 and 11, 1994, in a 2.5-mile section of the Nashua River that included two Fort Devens waste disposal sites and a former sewage disposal plant, USFWS personnel used electrofishing methods and trot lines to collect 43 fish from three trophic levels. Organochlorine and trace element concentrations were determined by USFWS contract analytical laboratories in 52 tissue samples - 28 fillet and 15 composite carcass samples (body minus fillet) of largemouth bass (*Micropterus salmoides*), brown bullhead (*Ameiurus nebulosus*), and yellow bullhead (*Ameiurus natalis*), and 9 wholebody composite samples of yellow perch (*Perca flavescens*). Fillet and carcass data of bass and bullhead were combined to estimate wholebody concentrations.

Polychlorinated biphenyls (PCBs) and DDT were the most common organochlorine contaminants in fish tissue. Chlordane compounds and dieldrin were also detected. Nashua River yellow perch had the highest levels of PCBs, with an estimated mean concentration of 2.35 ppm (range: 1.52 - 3.28 ppm, wet weight) in wholebody samples. DDT was found in reconstructed wholebody bass (estimated mean 0.27 ppm) and wholebody perch (estimated mean 0.46 ppm) at concentrations that may pose a risk to ecological receptors. Organochlorine concentrations in bass and bullhead fillet samples were not highly elevated.

Several trace elements were also found in fish tissue. Concentrations of chromium (max. 44.63 ppm) and mercury (max. 0.49 ppm) in Nashua River whole fish may pose a risk to ecological receptors. Further investigation of these two elements is recommended. Arsenic, cadmium, lead, and selenium were detected at elevated concentrations in reconstructed wholebody and wholebody samples, and continued monitoring within established programs (e.g., Massachusetts Department of Environmental Protection's Fish Toxics Monitoring Program) is recommended. Copper, nickel, and zinc in wholebody tissue samples were detected at levels similar to those in fish in other New England watersheds.

Human health risks were not evaluated in this report. A separate assessment of the potential human health risks posed by the consumption of Nashua River fish fillets is recommended.

PREFACE

This report presents organochlorine and trace element concentrations in fish collected from the Fort Devens section of the Nashua River in Ayer, Massachusetts. Funding for this study was provided by Region 1 of the U.S. Environmental Protection Agency (EPA) within an interagency agreement between the U.S. Fish and Wildlife Service and EPA for technical assistance in the Superfund Program (EPA/IAG #DW14934248-01-F). The analytical work for this study was performed under Patuxent Analytical Control Facility Catalog No. 5030038, Purchase Orders #98210-4-1910 and #98210-4-1911. Fish were collected under Massachusetts Division of Fisheries and Wildlife Scientific Collection Permit Number 124.94SCF.

Questions and comments to this report are encouraged. Written inquiries should be sent to:

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ACKNOWLEDGEMENTS

Access to the Nashua River from Fort Devens was facilitated by Tom Poole, Fort Devens Natural Resources Specialist. Electrofishing support was provided by the USFWS Office of Fisheries Assistance in Laconia, New Hampshire. Everett McLaughlin, Tim Cipriani, Beth Rhinehart, and Dave Griesche of the Laconia office provided valuable logistical and technical support during fish sampling. Dave McDonald and Patti Tyler of the EPA Region 1 Office of Environmental Measurement and Evaluation in Lexington, Massachusetts, coordinated decontamination activities and provided field support during the study. Mark Tisa of the Massachusetts Division of Fish and Wildlife provided technical support and assistance in obtaining the scientific collection permit. Bob Maietta of the Massachusetts Department of Environmental Protection provided technical assistance and background material related to previous Nashua River fish sampling. Jim Byrne and and Susan Svirsky of EPA Region 1 provided administrative assistance and arranged funding for the study. Drew Major of the USFWS New England Field Office in Concord, New Hampshire, provided assistance with processing sample catalogs through the USFWS Patuxent Analytical Control Facililty. Kimber Sprankle from the USFWS Concord office prepared Figure 1.

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Appendix B. ECDMS Analytical Report - Trace elements. Catalog 5030038. Purchase Order No. 98210-4-1911. Research Triangle Institute. 47 pp.

INTRODUCTION

The Nashua River, a major tributary of the Merrimack River system, flows north through Fort Devens in Ayer, Massachusetts. Fort Devens was an active military installation from 1917 until 1995. In the 1980s, hazardous wastes were discovered on the installation, and on December 21, 1989, it was placed on the National Priorities List under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, commonly known as Superfund). The Main Post and North Post sections of Fort Devens were closed in 1996 under the provisions of the Base Realignment and Closure Act of 1990. The South Post remains an active training area for U.S. Army Reserve Forces.

During Superfund investigations of the installation, two areas near the Nashua River were identified as potential hazardous waste sites: Study Area 11 (Lovell Road Debris Area) and Study Area 10 (Landfill No. 6 or Construction Debris Area). A site assessment was performed for Study Area 10 in 1993 as part of the Main Post Site Investigation (A.D. Little, Inc. 1993), and a remedial investigation was conducted at Study Area 11 in 1995 (A.D. Little, Inc. 1995a). Study Area 11 is a 1-hectare (2.4-acre) landfill on the west bank of the Nashua River that received debris and wastes from 1975 to 1980 (A.D. Little, Inc. 1995a). Wetlands and intermittent streams at the Study Area 11 site drain into the Nashua River. Study Area 10 is a 32-hectare (80-acre) parcel approximately 731 meters (2,400 ft) west of the Nashua River (A.D. Little, Inc. 1995b). Study Area 10 may have been a landfill site for demolition material and other debris. Trout Brook borders the northern edge of Study Area 10 and empties into the Nashua River.

The Main Post Site Investigation (A.D. Little, Inc. 1993) and Study Area 11 remedial investigation (A.D. Little, Inc. 1995a) found highly elevated levels of trace elements and lower levels of organochlorine contaminants in Nashua River sediments (Table 1). Several of these contaminants were found at concentrations expected to cause biological effects in benthic organisms (Ingersoll *et al.* 1996, Long and Morgan 1991). The A.D. Little reports attribute contamination of Trout Brook sediments downstream of Study Area 10 and the contamination at Study Area 11 and its wetlands to overbank flooding of the Nashua River. For decades, the Nashua River received a myriad of contaminants from tanneries, stormwater drains, landfill runoff, and improper or unregulated disposal practices associated with commercial, municipal, and military activities. Attribution of sediment contamination in the river to one entity or activity is a problematic exercise.

Contaminants in Nashua River sediments, regardless of the source are a concern to the U.S. Army, State and federal regulatory agencies, and natural resource management agencies. Several of the contaminants (e.g., PCBs, DDT, Hg) found in elevated concentrations in sediments biomagnify in food chains and may pose threats to higher trophic levels. As a result of this concern, in 1994, the U.S. Environmental Protection Agency provided funds to the U.S. Fish and Wildlife Service to conduct a contaminant study of fish in the Fort Devens section of the Nashua River.

STUDY PURPOSE

The purpose of the study was to determine the concentrations of environmental contaminants in fillet, carcass, and wholebody samples of Nashua River fish, and to evaluate those concentrations by comparing them with other national, regional, and State fish tissue data.

STUDY AREA

This study was conducted at Fort Devens in central Massachusetts. The 3,755-hectare (9,280-acre) military installation is located approximately 56 kilometers (35 miles) northwest of Boston. Fort Devens is located in the Towns of Ayer, Shirley, Harvard, and Lancaster in Middlesex and Worcester counties.

The Nashua River drainage basin encompasses 1,370 square kilometers (530 square miles) in central Massachusetts (Nuzzo *et al*. 1997). The 4-km (2.5-mi.) section of the Nashua River sampled for this study is approximately 38 meters (125 feet) wide with depths ranging from 2 meters (. 6 feet) to 3 meters (. 10 feet). Current velocities (0.5 - 2.5 centimeters/second) are slow (A.D. Little 1995). Woody vegetation along the banks of the river is dominated by grey birch (*Betula populifolia*), white pine (*Pinus strobus*), northern red oak (*Quercus rubra*), red maple (*Acer rubrum*) and white oak (*Quercus alba*). Backwaters of the river support duckweed (*Lemna* spp.) and pickerelweed (*Pontederia cordata*). Snags are common in the river and along the banks. In stretches of the river with less overhead canopy, the shallow areas and banks support cattail (*Typha* spp.), woolgrass (*Scirpus cyperinus*), jewelweed (*Impatiens capensis*), and purple loosestrife (*Lythrum salicaria*). During USFWS fish sampling and field surveys, wildlife species observed along the river included spotted sandpiper (*Actitis macularia*), American robin (*Turdus migratorius*), mallard (*Anas platyrhynchos*), ruffed grouse (*Bonasa umbellus*), blue jay (*Cyanocitta cristata*), great blue heron (*Ardea herodias*), great-horned owl (*Bubo virginianus*), American crow (*Corvus brachyrhynchos*), gray catbird (*Dumetella carolinensis*), red-winged blackbird (*Agelaius phoeniceus*), and painted turtle (*Chrysemys picta*).

METHODS

Between August 9 and 11, 1994, fish were collected from a 4-kilometer (2.5-mile) stretch of the Nashua River between State Highway Route 2 and Ayer Road/West Main Street. Fish were collected from three river reaches identified as **SDP1**, **SA 11,** and **SA 10** (Figure 1). Sixteen largemouth bass (*Micropterus salmoides*), five brown bullhead (*Ameiurus nebulosus*), seven yellow bullhead (*Ameiurus natalis*), and fifteen yellow perch (*Perca flavescens*) were collected from the three river reaches. Most of the fish were collected from a boom-type electrofishing boat, although a few of the bullhead were caught on trot lines baited with fish captured from the Nashua River.

The maximum total length in centimeters and the total weight to the nearest gram were measured for each fish (Table 3). Prior to processing, each fish was examined for external abnormalities. Largemouth bass and bullhead were filleted, and the fillets were weighed to the nearest gram (Table 4). Bass and bullhead fillet (skin-off) and carcass samples (the remainder of the fish including offal and skin from fillets) were wrapped in aluminum foil (dull side towards sample), labeled and placed in plastic freezer bags. Intact wholebody perch were packaged similarly. Samples were immediately placed on dry ice in coolers and transported to freezers for storage at -20^{0}C. Fifty-two tissue samples were submitted for contaminant analyses (Table 4): 28 fillets, 15 carcass and carcass composites (body minus fillet), and 9 wholebody and wholebody composites.

Fillets were the priority samples for EPA. Due to limited funding, individual carcass and wholebody samples could not be analyzed. Therefore, some carcass and wholebody samples were composited. The composites included similar-sized fish of the same species.

Upper trophic level piscivores usually consume the entire fish. To evaluate the potential hazards to piscivorous wildlife posed by environmental contaminants in whole fish, and to facilitate comparisons with other fish tissue studies, we combined fillet and carcass information to generate a "reconstructed" wholebody concentration. The wholebody reconstruction formula was:

$$RWC = (FB + CB)/TW$$

where RWC is the reconstructed wholebody concentration
FB is the fillet burden (i.e., fillet weight * fillet concentration),
CB is the carcass burden (i.e., carcass weight * carcass concentration), and
TW is the combined weight of the fillet and carcass.

Samples that included composites were similarly reconstructed. The contaminant burdens of individual samples within the composites (e.g., fillets from different fish) were calculated and combined with carcass data (see equation at end of Table 4).

RESULTS OF CHEMICAL ANALYSES

All fish tissue samples were analyzed for trace elements, organochlorine pesticides, and polychlorinated biphenyls (Aroclor-specific) under the direction of the USFWS's Patuxent Analytical Control Facility (PACF). Organochlorine pesticide and PCB analyses were conducted by the Mississippi State Chemical Laboratory, Mississippi State, MS (Appendix A). Trace element analyses were performed by the Research Triangle Institute, Research Triangle Park, NC (Appendix B). Methods used by the laboratories are included in the appendices. Contaminant data are presented throughout this report in : g/g (ppm), **wet weight**. Tissue concentrations were not normalized based on percent lipid. Lipid content is reported in Appendix A for those who prefer lipid-normalized data and wish to convert organochlorine contaminant concentrations.

Quality Control

Quality assurance and control were accomplished through the use of spike recoveries and the analysis of duplicate samples, reagent blanks, and reference materials. The analytical packages from the Mississippi State Chemical Laboratory and the Research Triangle Institute were reviewed by the PACF. Organochlorine analytical data were approved with comment (Appendix A, page 54). PACF found that spike recoveries were acceptable, but slightly below normal levels for HCB, delta BHC, dieldrin, and p,p' DDD. The spike recovery results for dieldrin and p,p' DDD indicate that the true concentrations of these two compounds may be slightly higher than the amount reported. The trace element results were approved without comment (Appendix B, page 45). Examination of analytical data during preparation of this report led the authors to conclude that chromium levels in yellow perch samples were unusually high. At the request of the authors, PACF re-examined the data and reported no abnormalities in the laboratory procedures or data package.

Data Presentation

Descriptive statistics in this report include geometric mean, arithmetic mean, standard deviation, standard error and ranges. Figure 2 (fillets) and Figure 3 (reconstructed wholebody and wholebody composites) illustrate mean contaminant concentrations for the three fish trophic levels. Table 5 summarizes contaminant results by fish trophic level. Tables 6 through 20 list results for individual samples by species and contaminant group. The means reported in the Results and Discussion sections of this report are geometric means (Θ_G) for fillets and arithmetic means (Θ_A) for reconstructed wholebody and wholebody composites. Since several reconstructed wholebody and wholebody samples are composites of two or more fish, the means should be considered estimates. Mean contaminant concentrations were only calculated if one-half or more had detectable levels of a contaminant. For contaminants detected in half or more of the samples, means were calculated by incorporating one-half of the detection limit (inorganics) or one-half of the method detection limit (organochlorines) for samples reported as "non-detects." When contaminants were found in only a few samples for a species, the range or individual sample results are provided.

Organochlorine Results

The organochlorine analyses included twenty-five compounds (Appendix A): HCB (hexachlorobenzene), Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260, alpha BHC (hexachlorocyclohexane), *alpha* chlordane (*cis*-chlordane), *beta* BHC, *cis*-nonachlor, *delta* BHC, dieldrin, endrin, *gamma* BHC (lindane), *gamma* chlordane (*trans*-chlordane), heptachlor epoxide, mirex, o,p'-DDD, o,p'-DDE, o,p'-DDT, oxychlordane, p,p'-DDD, p,p'-DDE, p,p'-DDT, toxaphene, and *trans*-nonachlor.

HCB, Aroclor-1242, *alpha* BHC, *beta* BHC, *delta* BHC, endrin, *gamma* BHC, heptachlor epoxide, mirex and toxaphene were <u>not detected</u> in fish tissue samples from the Nashua River. Consequently, these compounds are not be discussed in this report.

Figure 2 depicts organochlorine results in bass and bullhead fillets. Figure 3 is a plot of organochlorine results in reconstructed wholebody largemouth bass and bullheads, and wholebody yellow perch samples. The y-axis on both figures is a logarithmic normal scale. Tables 6 through 15 show concentrations of organochlorines in individual samples.

'PCBs - 'PCB is the sum of the concentrations of Aroclor-1248, Aroclor-1254, and Aroclor-1260 (Aroclor-1242 was not detected in Nashua River fish). PCBs were detected in 14 bass fillet samples (Table 6). The 'PCB concentration in all bass fillets range from non-detect to 1.08 : g/g, and the geometric mean concentration is 0.27 : g/g. In bullhead fillets, PCBs were detected in 11 of 12 samples (Table 8). The geometric mean 'PCB concentration in bullhead fillets is 0.15 : g/g (range: non-detect to 0.67 : g/g). In reconstructed wholebody and wholebody samples, the estimated arithmetic mean 'PCB concentrations are 1.01 : g/g in bass (Table 7), 0.46 : g/g in bullhead (Table 9), and 2.35 : g/g in yellow perch (Table 10).

'DDT - 'DDT is the sum of ortho and para forms of DDE, DDD and DDT. In bass fillets, DDT metabolites were detected in 15 of 16 samples (Table 6). The geometric mean 'DDT concentration in bass fillets is 0.05 : g/g (range: non-detect to 0.23 : g/g). Compared to bass fillets, fewer DDT metabolites and lower concentrations were detected in bullhead fillets. The geometric mean 'DDT concentration in bullhead fillets is 0.01 : g/g (Table 8). Five of the 12 bullhead fillet samples did not contain detectable levels of DDT metabolites; therefore one-half the method detection limit was used to compute the 'DDT geometric mean. In reconstructed wholebody and wholebody samples (Tables 7, 9, and 10), 'DDT is highest in yellow perch (θ_A 0.46 : g/g) followed by largemouth bass (θ_A 0.27 : g/g) and bullhead (θ_A 0.07 : g/g).

Chlordane Compounds - Five chlordane compounds were detected in Nashua River fish tissue: *alpha* chlordane, *gamma* chlordane, *cis*-nonaclor, *trans*-nonaclor, and oxychlordane. Reconstructed wholebody and wholebody samples had higher residues of chlordane than fillets. Only one bass fillet (Table 11) contained a chlordane compound: *alpha* chlordane at 0.013 : g/g (SDP1-LmB-2F). Chlordane compounds were not detected in bullhead fillets (Table 13).

Reconstructed wholebody largemouth bass had detectable concentrations of 3 chlordane compounds (Table 12). *Alpha* chlordane and *trans*-nonachlor were detected in 6 of the 9 samples. Detectable levels of *alpha*-chlordane range from 0.008 to 0.023 : g/g, while *trans*-nonachlor ranges from 0.009 to 0.021 : g/g. *Cis*-nonachlor was detected in two reconstructed wholebody bass (0.009 : g/g and 0.010 : g/g). Chlordane was found in only one brown bullhead reconstructed wholebody sample, *alpha*-chlordane at 0.0126 : g/g in SDP1-BBH-5 (Table 14). Five chlordane compounds were detected in yellow perch wholebody samples (Table 15). *Alpha* chlordane (θ_A 0.03 : g/g, range 0.017 - 0.060 : g/g) and *trans*-nonachlor (θ_A 0.03 : g/g, range 0.013 - 0.054 : g/g) were detected in all perch samples. *Cis*-nonachlor was detected in 7 of 9 samples (range: 0.010 - 0.024 µg/g), oxychlordane in 5 of 9 perch samples (range: 0.010 - 0.014 µg/g), and *gamma* chordane in 2 samples (both 0.010 µg/g).

Dieldrin - Dieldrin was infrequently detected in Nashua River fish samples. Fillets of largemouth bass (Table 11), fillets of bullhead (Table 13) and reconstructed wholebody bullhead (Table 14) did not contain detectable levels of dieldrin. Dieldrin was found in one largemouth bass reconstructed wholebody sample: SA11-LmB-7 at 0.01 µg/g (Table 12). All but one of the yellow perch wholebody samples contained detectable levels of dieldrin. The estimated mean dieldrin concentration in perch is 0.01 µg/g (Table 15).

<u>Trace Element Results</u>

Trace element analyses included 19 analytes (Appendix B) - aluminum, arsenic, boron, barium, beryllium, cadmium, chromium, copper, iron, mercury, magnesium, manganese, molybdenum, nickel, lead, selenium, strontium, vanadium, and zinc. Boron and beryllium were <u>not detected</u> in any samples.

In New England, fish tissue concentrations of aluminum, barium, iron, magnesium, manganese, strontium, and vanadium are generally not evaluated as contaminants of concern. The reason, in part, is because relatively little information exists to evaluate the potential toxic effects of these contaminants in fish tissue. Consequently, it is not known if the concentrations detected in Nashua River fish are low or high, and if these contaminants are likely to cause toxic effects in fish or pose a risk to piscivorous receptors. These analytes are not discussed in this report, but the analytical results for these elements are included in Appendix B.

Figure 2 illustrates trace element results in bass and bullhead fillets. Figure 3 shows trace element results in reconstructed wholebody largemouth bass and bullhead, and wholebody yellow perch samples. The y-axis on both figures is a logarithmic normal scale. Tables 16 through 20 show concentrations of trace elements in individual samples.

Arsenic (As) - Arsenic was detected in three fillet samples - 2 largemouth bass and 1 bullhead (Tables 16 and 18). The As concentrations in the largemouth bass fillets are 0.11 µg/g (SDP1-LmB-4F) and 0.21 µg/g (SDP1-LmB-5F). In the bullhead fillet (SDP1-BBH-2F), the As concentration is 0.35 µg/g. The estimated arithmetic mean As concentrations in reconstructed wholebody and wholebody samples are 0.45 µg/g in largemouth bass (Table 17), 0.32 µg/g in bullhead (Table 19), and 0.45 µg/g in yellow perch (Table 20).

Cadmium (Cd) - Cadmium was not detected in largemouth bass fillets, and was detected in only three bullhead fillets (Table 18). These three fish were collected from the SA11 reach. The mean Cd concentration in the three bullhead fillets is 0.02 µg/g, while reconstructed wholebody bullhead have an arithmetic mean concentration of 0.15 µg/g (Table 19). The mean Cd concentration in reconstructed wholebody bass is 0.08 : g/g (Table 17), and the mean in wholebody perch is 0.11 : g/g (Table 20).

Chromium (Cr) - Although Cr was not detected in largemouth bass or bullhead fillets (Tables 16 and 18), all reconstructed wholebody and wholebody samples contained Cr. Chromium concentrations are markedly higher in yellow perch wholebody samples than in bass or bullhead reconstructed wholebody samples. The estimated arithmetic mean Cr concentration in perch wholebody samples is 13.51 : g/g. The variability of concentrations among these samples is high (range: 0.89 - 44.63 : g/g, Table 20). Six of the 9 perch samples had Cr concentrations in excess of 4 : g/g. Reconstructed wholebody bass and bullhead Cr concentrations are considerably lower than wholebody yellow perch. The estimated mean Cr concentration in reconstructed wholebody bass is 0.70 : g/g (range: 0.52 - 0.99 : g/g; Table 17), and the mean in bullhead is 0.82 : g/g (range: 0.44 - 1.76 : g/g; Table 19).

Copper (Cu) - Copper was detected in all fillet samples of largemouth bass (Θ_G 0.34 : g/g, Table 16) and bullhead (Θ_G 0.38 : g/g; Table 18). Copper concentrations in reconstructed wholebody bass and bullhead, and wholebody samples of perch are similar. The estimated arithmetic mean Cu concentrations are 1.10 : g/g (range: 0.56 - 1.82 : g/g; Table 17) in reconstructed wholebody bass, 0.99 : g/g (range: 0.51 - 1.93 : g/g; Table 19) in reconstructed wholebody bullhead composites, and 1.04 : g/g (range: 0.57 - 1.91 : g/g; Table 20) in wholebody yellow perch.

Mercury (Hg) - Mercury was detected in all largemouth bass and bullhead fillet samples (Tables 16 and 18). The geometric mean Hg concentrations in largemouth bass and bullhead fillets are 0.33 : g/g and 0.26 : g/g, respectively. The estimated arithmetic mean Hg concentration in largemouth bass reconstructed wholebody is 0.24 : g/g (Table 17). Mean Hg concentrations in bullhead reconstructed wholebody (Θ_A 0.20 : g/g; Table 19) and wholebody yellow perch (Θ_A 0.16 : g/g; Table 20) are lower than reconstructed wholebody bass.

Nickel (Ni) - Nickel was not detected in largemouth bass fillet or carcass samples. Nickel was not detected in bullhead fillets, but was detected in 3 of 6 carcass samples. The reconstructed wholebody bullhead Ni concentrations are 0.11 : g/g, 0.18 : g/g, and 0.19 : g/g (Table 19). Nickel was detected in 5 of the 9 wholebody yellow perch samples (Table 20). Since over half of the yellow perch samples contained detectable levels of Ni, one-half the sample detection limit was used for non-detects in the computation of the arithmetic mean. The estimated mean Ni concentration in yellow perch wholebody samples is 0.26 : g/g.

Lead (Pb) - Lead was not detected in largemouth bass or bullhead fillets. Three of 9 largemouth bass reconstructed wholebody samples contained detectable levels of lead - 0.29 : g/g, 0.30 : g/g, and 0.45 : g/g (Table 17). Lead was detected in 5 of 6 bullhead reconstructed wholebody samples and the estimated arithmetic mean is 0.59 : g/g (range: nd - 1.11 : g/g; Table 19). All yellow perch wholebody samples contained Pb. Lead concentrations in perch range from 0.57 : g/g to 1.55 : g/g (Θ_A 1.06 : g/g; Table 20).

Selenium (Se) - Selenium was detected in all largemouth bass and bullhead fillet samples. The geometric mean Se concentrations in bass and bullhead fillets samples are 0.56 : g/g (Table 16) and 0.29 : g/g (Table 18), respectively. All bass and bullhead reconstructed wholebody samples and yellow perch wholebody samples also contained Se. Selenium is highest in wholebody yellow perch (Θ_A 0.86 : g/g, range: 0.54 - 1.20 : g/g; Table 20), followed by reconstructed wholebody bass (Θ_A 0.54 : g/g, range: 0.43 - 0.69 : g/g; Table 17) and bullhead (Θ_A 0.44 : g/g, range: 0.29 - 0.64 : g/g; Table 19).

Zinc (Zn) - Zinc was detected in all largemouth bass and bullhead fillet samples (Tables 16 and 18). The geometric mean Zn concentrations in bass and bullhead fillets are 6.23 : g/g and 7.48 : g/g, respectively. Zinc is highest in reconstructed wholebody bullhead (Θ_A 23.39 : g/g; Table 19). Estimated mean concentrations in reconstructed wholebody largemouth bass and wholebody yellow perch are 20.42 : g/g (Table 17) and 22.45 : g/g (Table 20), respectively.

DISCUSSION

In this section, brief notes on the characteristics of each contaminant are presented. The concentrations of each contaminant detected in Nashua River fish are compared with data from national, regional, or State sources, or levels reported in the scientific literature. In some instances, the potential effect of the contaminant burden to fish is also briefly discussed. Finally, the potential risk the tissue contaminant level may have on fish and wildlife species that consume Nashua River fish (i.e., piscivores) is *qualitatively* noted.

Nashua River fish contaminant concentrations were compared against several data sources. National mean levels of trace elements and organochlorines were reported in the U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program (NCBP; Schmitt and Brumbaugh 1990, Schmitt *et al*. 1990). The NCBP tracks temporal and geographic trends in contaminant concentrations in composite samples of whole fish collected from 112 riverine stations throughout the United States. The latest results of the NCBP include fish collected in 1984. We used the NCBP results extensively for comparative purposes and recognize the limitations associated with the data set. The geometric mean and 85th percentile concentrations reported in the NCBP have no regulatory significance or meaning with respect to potential hazard to fishery resources (May and McKinney 1981), but serve as relative statistical reference points to distinguish among contaminant concentrations in fish.

Regional sources include data from Maine (Sowles *et al.* 1997), New Hampshire (Major and Carr 1991), and Connecticut (USFWS, unpublished data). State data included mercury results reported by the Massachusetts Department of Environmental Protection (MADEP 1997), the Massachusetts portion of a USFWS study of the Merrimack River (Major and Carr 1991), Nashua River watershed investigations by the MADEP (Maietta 1986, Nuzzo *et al.* 1997), a USFWS study at the Oxbow National Wildlife Refuge on the Nashua River (USFWS, unpublished data), a USFWS fish tissue contaminant study at Grove Pond in Ayer (Mierzykowski *et al*. 1993), and information from studies on the Sudbury River (Eaton and Carr 1991, Haines *et al*. 1998). These data sets should be reviewed with caution. In several instances, the studies were undertaken by regulatory or natural resource agencies because a contaminant problem was suspected (i.e., a hazardous waste site). The problem is compounded by the region's history. Many industrial, commercial or municipal entities that generated hazardous wastes are located adjacent to the region's surface waters. Vehicular traffic on highways and secondary roads located near surface waters also contribute environmental contaminants to the region's aquatic systems. Improper disposal practices, accidental discharges, or stormwater runoff also introduce contaminants to aquatic systems. Consequently, unimpacted or "clean" areas are rare. Moreover, atmospheric deposition has also introduced contaminants to the region. The Massachusetts and regional data sets should be viewed in the aforementioned context.

Highly elevated fish tissue concentrations are illustrated by examples from highly contaminated sites and biological effect levels from the scientific literature. Contaminant concentrations reported on a dry weight basis in any of these sources were converted to wet weight based on a presumed 75% moisture concentration in fish flesh. The values reported in these various studies include many different species and sizes, fillet and wholebody concentrations, and fish collected from contaminated and uncontaminated sites. Overall, the compilation of concentrations from regional, State, and literature sources cited in this report are presented only for comparative purposes.

The discussion section deals primarily with contaminant exposure and the potential effects of fish contamination on ***ecological receptors***. Brief notes regarding some fillet contaminant concentrations and FDA Action or Tolerance Levels or state health advisories are included for context. In some instances, fillet data are compared with other data sets. A separate assessment of our fillet data would be necessary in order to determine the human health implications of contaminants in Nashua River fish. Our use of FDA Action Levels or state advisories for comparative purposes should not be considered an assessment of risk to humans. Similarly, this report should not be considered an ecological risk assessment as defined by CERCLA. This study will be provided to risk assessors of EPA and the Massachusetts Department of Environmental Protection, who may provide a more detailed evaluation of the potential human and ecological health risks associated with the consumption of Nashua River fish.

Organochlorines

• **PCBs** - PCBs are lipophilic compounds that bioconcentrate in organisms (EPA 1980), and biomagnify in food chains (Eisler 1986a). In fish, acute toxicity from PCBs is low, while chronic toxicity is relatively high (Murty 1986). PCB accumulations can adversely affect egg survival and fry development in fish (Hogan and Brauhn 1975). Niimi (1996) reported that fish from higher trophic levels in uncontaminated freshwater environments had PCB concentrations in the low µg/kg (ppb) range, while higher trophic level fish from contaminated waters had PCB levels in the low µg/g (ppm) range. In riverine systems, biomagnification of PCBs has occurred more from the ingestion of contaminated prey (i.e., trophic transfer) than uptake from water (Zaranko *et al*. 1997). Fish with tissue PCB concentrations of >50 to 100 µg/g may experience adverse changes in growth and reproduction (Niimi 1996). PCBs are common contaminants in piscivorous birds and mammals. Certain mammals may be particularly at risk from PCBs. Mink (*Mustela vison*), for example, are extremely sensitive to PCBs, and diets with PCB concentrations of 0.67 : g/g could lead to reproductive failure (Ringer 1983).

In this study, PCBs are highest in Nashua River yellow perch wholebody samples (θ_A 2.35 : g/g, range 1.52 - 3.28 : g/g), followed by reconstructed wholebody largemouth bass (θ_A 1.01 : g/g) and bullhead (θ_A 0.46 : g/g). These levels are generally higher than PCB fish tissue concentrations from uncontaminated areas reported in national studies. The geometric mean PCB concentration reported for the NCBP (Schmitt *et al.* 1990) is 0.39 : g/g.

Compared to other Massachusetts and regional studies, PCB concentrations in Nashua River reconstructed wholebody and wholebody fish samples are higher than some areas and lower than others. In a USFWS fish tissue investigation at Grove Pond (Mierzykowski *et al.* 1993), an Ayer, MA, pond that borders Fort Devens, the geometric mean PCB concentration of 10 largemouth bass was 0.22 : g/g (reconstructed wholebody). In the nearby Sudbury River system, Eaton and Carr (1991) reported total PCB concentrations in yellow perch wholebody composite samples ranging from non-detect to 4.20 : g/g. Nine of their 13 samples exceeded 2.00 : g PCB/g. In the Merrimack River, Major and Carr (1991) reported PCB concentrations of 1.45 : g/g, 0.70 : g/g, and 0.87 : g/g in wholebody samples of smallmouth bass, brown bullhead, and yellow perch, respectively.

< The PCB concentrations in Nashua River fish exceed the wholebody protection criterion of 0.40 : g/g proposed by Eisler and Belisle (1996), the dietary protection criterion for piscivorous wildlife of 0.10 : g/g listed in the Great Lakes Water Quality Agreement of 1978 (IJC 1989), and the fish flesh criterion of 0.11 : g/g developed by New York State for the protection of piscivorous wildlife in the Niagra River (Newell *et al.* 1987). Consequently, some wildlife foraging on fish from the Fort Devens section of the Nashua River may be adversely affected by PCB contamination.

The FDA promulgated a Tolerance Level for PCBs of 2 : g/g for edible portions of fish sold commercially (FDA 1992). PCBs in largemouth bass (θ_G 0.27 : g/g) and bullhead (θ_G 0.15 : g/g) fillets from the Nashua River do not exceed the FDA Tolerance Level. Wholebody yellow perch samples contain an estimated mean ' PCB concentration of 2.35 : g/g. If we assume that PCBs in yellow perch are partitioned in a ratio similar to the 4:1 reconstructed wholebody to fillet ratio in Nashua River bass and bullhead, we would expect PCB concentrations in Nashua River yellow perch fillets to be below the FDA Tolerance Level.

' DDT - DDT and its metabolites are persistent contaminants in the environment. Although the use of DDT in the United States was essentially discontinued in 1972 (EPA 1990), the compound and its metabolites continue to be detected in fish and wildlife tissues. DDT metabolites are lipophilic and accumulate in lipid deposits and other fatty tissues (Moore and Ramamoorthy 1984a). Chronic exposure to sublethal concentrations of DDT metabolites and other pesticides can cause a number of adverse effects in fish including changes in morphology, behavior, biochemistry, hematology, histopathology, respiration, feeding and growth, reproduction, and development of early life stages (Murty 1986). In raptors and piscivorous birds, DDT metabolites cause eggshell thinning (Hickey and Anderson 1968). Eggs of piscivorous birds with DDE residues of 1 : g/g have a 5% to 10% reduction in eggshell thickness, and eggshells with 18% thinning are associated with declining populations (Blus 1996). DDE was also found to thin eggshells and reduce reproductive success in captive black ducks (Longcore *et al*. 1971) and mallards (*Anas platyrhynchos*; Heath *et al*. 1969).

The NCBP (Schmitt *et al*. 1990) geometric mean EDDT concentration is 0.26 : g/g. The reconstructed wholebody largemouth bass GDDT concentration (Θ_A 0.27 : g/g) from the Fort Devens section of the Nashua River is slightly above the NCBP geometric mean, while the estimated mean for reconstructed wholebody bullhead (Θ_A 0.07 : g/g) is well below the NCBP mean for GDDT. Total DDT was highest in Nashua River yellow perch wholebody samples. The estimated mean in perch (Θ_A 0.46 : g/g) is nearly twice as high at the NCBP geometric mean. The elevated GDDT concentrations in Nashua River fish are not unique to the area. In the adjoining Sudbury River system, Eaton and Carr (1991) reported GDDT concentrations in wholebody yellow perch ranging from 0.07 to 0.59 : g/g. Eleven of their 13 samples exceeded the NCBP GDDT geometric mean. In Merrimack River fish, GDDT concentrations were lower than fish from the Fort Devens section of the Nashua River. Wholebody composites of smallmouth bass, brown bullhead, and yellow perch from the Merrimack had DDT concentrations of 0.17 : g/g, 0.05 : g/g and 0.11 : g/g respectively (Major and Carr 1991).

< New York State proposed a fish flesh EDDT concentration of 0.2 : g/g to protect piscivorous birds (Newell *et al*. 1987). Reconstructed wholebody bass and wholebody samples of yellow perch from the Fort Devens section of the Nashua River were above the NYS EDDT criterion. Based on Newell's assessment, we expect that piscivorous bird species consuming Nashua River bass and perch would be at risk from DDT.

The Food and Drug Administration Action Level for EDDT metabolites in the edible portion of fish is 5 : g/g (FDA 1992). Nashua River bass and bullhead fillet concentrations are considerably lower than the FDA action level.

Chlordane Compounds - Chlordane was widely used since the late 1940s throughout the United States as a broad spectrum insecticide. It was regularly used for subterranean termite control. All commercial uses of chlordane were canceled in the United States in 1988 (Howard 1991). Chlordane, however, persists for years in soil, sediment and biota. The immediate toxicity of chlordane varies depending on the species and life stage, but in general can be considered moderately toxic to mammals, moderately to highly toxic to birds, and highly toxic to fish and aquatic insects (Briggs 1992, von Rumker *et al*. 1975).

Alpha (*or cis*)-Chlordane: The NCBP (Schmitt *et al*. 1990) geometric mean *alpha*-chlordane concentration is 0.03 : g/g and the maximum is 0.66 : g/g. *Alpha*-chlordane was found in 6 of 9 bass reconstructed wholebody samples with concentrations ranging from 0.008 :g/g to 0.023 :g/g. In reconstructed wholebody bullhead, *alpha*-chlordane was detected once at a concentration of 0.0126 :g/g (Sample No. SDP1-BBH-5C). All yellow perch wholebody samples contained *alpha*-chlordane. Although 5 of the 9 perch samples exceeded the NCBP geometric mean concentration, the estimated mean (θ_A 0.03 :g/g) is the same as the NCBP.

Cis-nonachlor: The NCBP (Schmitt *et al*. 1990) geometric mean *cis*-nonachlor concentration is 0.02 :g/g and the maximum is 0.45 :g/g. *Cis*-nonachlor was detected in 2 of the 9 Nashua River reconstructed wholebody bass samples at concentrations of 0.009 :g/g (SDP1-LmB-7C) and 0.010 :g/g (SA10-LmB-8C). The compound was not detected in bullhead carcasses. *Cis*-nonachlor was detected in 7 of 9 yellow perch wholebody samples at concentrations ranging from 0.010 :g/g to 0.024 :g/g. Compared to other data, *cis*-nonachlor levels in Nashua River fish do not appear to be highly elevated.

Gamma (*or trans*)-Chlordane: The geometric mean *gamma*-chlordane concentration in the NCBP (Schmitt *et al*. 1990) is 0.02 :g/g and the maximum is 0.35 :g/g. *Gamma*-chlordane was not detected in fillet or carcass samples of Nashua River bass and bullhead, and detected in two perch wholebody samples at a concentration of 0.01 :g/g. Based on these results, *gamma*-chlordane does not appear to be a contaminant of concern in fish from this section of the Nashua River.

Oxychlordane: The oxychlordane geometric mean concentration in the NCBP (Schmitt *et al*. 1990) is 0.01 :g/g and the maximum is 0.29 :g/g. Oxychlordane was not detected in Nashua River bass or bullhead fillet or carcass samples. Five of 9 yellow perch wholebody samples contained oxychlordane, with individual concentrations of 0.010 :g/g to 0.014 :g/g. These concentrations in Nashua River perch are not highly elevated compared to the NCBP.

Trans-nonachlor: In the NCBP (Schmitt *et al*. 1990) the geometric mean *trans*-nonachlor concentration is 0.03 :g/g and the maximum is 1.00 :g/g. *Trans*-nonachlor was detected in 6 of 9 Nashua River bass reconstructed wholebody samples (range: 0.008 - 0.021 :g/g) and all yellow perch wholebody samples (θ_A 0.03 :g/g). The compound was not detected in bullhead. Compared to the NCBP mean, *trans*-nonachlor is not remarkable in Nashua River fish.

< Chlordane muscle residues of 0.1 :g/g may endanger fish health in some species (Eisler 1990). New York State proposed a fish flesh chlordane concentration of 0.37 :g/g (cancer endpoint) and 0.500 :g/g (non-cancer endpoint) to protect piscivorous birds (Newell *et al*. 1987). The low frequency of detection of chlordane compounds in bass and bullhead samples and the low concentration of total chlordane (i.e., the sum of all the compounds) in Nashua River fish samples (bass θ_A 0.022 :g/g, perch θ_A 0.091 :g/g) suggest that these compounds are not contaminants of concern in this portion of the river.

The Food and Drug Administration Action Level for chlordane residues in fish muscle is 0.3 :g/g, wet weight (FDA 1992). Chlordane was not detected in bullhead fillets and detected in only one bass fillet at a concentration of 0.013 : g/g (*alpha* chlordane).

Dieldrin - Dieldrin is a persistent insecticide that is insoluble in water and highly toxic to fish and aquatic insects (Briggs 1992). It is one of the most toxic organochlorines that has been implicated in several cases of acute poisoning in wildlife (Blus 1995). Dieldrin contamination is generally associated with pesticide applications. However, atmospheric deposition can also introduce dieldrin to remote ecosystems. In four remote lakes in Maine, Haines (1983) detected dieldrin in Age I brook trout ranging from 0.003 to 0.007 : g/g.

The NCBP (Schmitt *et al*. 1990) geometric mean dieldrin concentration is 0.04 : g/g and the maximum is 1.39 : g/g. Compared to the NCBP, dieldrin does not appear to be a significant contaminant in Nashua River fish. None of the reconstructed wholebody or wholebody tissue samples (max. 0.02 : g/g) approached the NCBP geometric mean concentration. Dieldrin was detected in 8 of 9 perch wholebody composite samples (θ_A 0.01 : g/g) and in one bass carcass composite at a concentration of 0.01 : g/g. Dieldrin was not detected in bullhead carcass samples.

< New York State proposed a fish flesh dieldrin concentration of 0.022 : g/g (cancer endpoint) and 0.12 : g/g (non-cancer endpoint) to protect piscivorous birds (Newell *et al*. 1987). The concentrations in Nashua River fish do not exceed the NYS dieldrin criteria.

The Food and Drug Administration Action Level for dieldrin residues in fish muscle is 0.3 : g/g, wet weight (FDA 1992). Dieldrin was not detected in Nashua River bass or bullhead fillets.

<u>Trace elements</u>

Arsenic (As) - Arsenic is a teratogen and carcinogen, which bioconcentrates in organisms, but does not biomagnify in food chains (Eisler 1994). In toxicity tests, early life stages of fish (muskellunge, *Esox masquinongy*) were vulnerable to arsenic (Spotila and Paladino 1979). In unpolluted or mildly-contaminated waters, fish tissue may contain As residues ranging between < 0.1 and 0.4 : g/g (Moore and Ramamoorthy 1984b). Fish exposed to high concentrations of arsenic in water can accumulate the contaminant in tissue over a short period of time. Green sunfish (*Lepomis cyanellus*) placed in water with an arsenic concentration of 100 mg/L had tissue concentrations of 33.4 : g/g after 46 hours (Sorensen 1976). Arsenic readily accumulates in fish, particularly in the liver and skin (Oladimeji *et al*. 1984). Spehar *et al*. (1980) suggested that fish may have the ability to metabolize arsenic more efficiently than lower food chain organisms. There is limited information on the potential effects of arsenic accumulation by freshwater fish. Gilderhus (1966) reported that immature bluegills (*Lepomis macrochirus*) with tissue residues greater than 1.3 : g As/g experienced diminished growth and survival. Dietary exposure to arsenic (7.5 : g/g) also reduced growth in rainbow trout (Oladimeji *et al*. 1984).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean As concentration is 0.14 : g/g and the 85th percentile is 0.27 : g/g. Compared to the NCBP, arsenic was elevated in fish tissue from the Fort Devens section of the Nashua River. The estimated mean concentrations of As in reconstructed wholebody bass (Θ_A 0.45 : g/g), bullhead (Θ_A 0.32 : g/g) and wholebody perch (Θ_A 0.45 : g/g) samples exceed the NCBP 85th percentile. Nashua River fish also have higher As concentrations than fish from a neighboring river system. Yellow perch and brown bullhead wholebody composite samples collected from the Sudbury River, Concord River, and Assabet River in 1986 and 1987 had arsenic concentrations ranging from 0.03 to 0.06 : g/g and 0.02 to 0.08 : g/g, respectively (Eaton and Carr 1991).

< Although elevated, we do not believe the arsenic concentrations in fish from the Fort Devens section of the Nashua River warrant any action relative to the protection of ecological receptors other than continued monitoring within established programs. The fish tissue concentrations are well below the 1.3 : g/g adverse effect level cited by (Gilderhus 1966), and the sediment levels (Table 1) are below biological effect concentrations (Ingersoll *et al.* 1996).

Arsenic was detected in only 2 of 16 bass fillet samples (0.11 : g/g and 0.21 : g/g) and in one bullhead fillet sample (0.35 : g/g).

Cadmium (Cd) - Cadmium is a teratogen, possible carcinogen, and probable mutagen, that has been implicated as the cause for severe effects in fish and wildlife (Eisler 1985a). In humans, chronic exposure to Cd can lead to kidney dysfunction (FDA 1993a). Vertebrate species with wholebody concentrations of 2.0 : g/g likely indicate Cd contamination (Eisler 1985a). Animals with Cd tissue concentrations greater than 5 : g/g may be lethally affected by Cd, while higher tissue concentrations of 15.0 : g/g could be hazardous to the upper trophic level species that prey on these animals (Eisler 1985a). Spry and Wiener (1991) reported that Cd does not increase with fish age or size, does not biomagnify in aquatic food chains, and primarily accumulates in gill, kidney, and liver tissue. Consequently, wholebody concentrations are useful bioindicators of fish exposure to Cd (Cope *et al*. 1994). In highly contaminated areas, Cd in wholebody fish may be as high as 3 : g/g (Murphy *et al*. 1978). In uncontaminated areas, wholebody Cd levels in fish may range from 0.02 to 0.09 : g/g (Murphy *et al.* 1978).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Cd concentration is 0.03 : g/g and the 85th percentile is 0.05 : g/g. Cadmium in fish from the Fort Devens section of the Nashua River were higher than the NCBP with the highest estimated mean concentration occurring in reconstructed wholebody bullhead (Θ_A 0.15 : g/g, range 0.03 - 0.23 : g/g). Yellow perch wholebody samples (Θ_A 0.11 : g/g) and reconstructed wholebody bass (Θ_A 0.08 : g/g) also have estimated mean concentrations higher than the NCBP geometric mean and 85th percentile.

< Cadmium may be a potential contaminant of concern in fish tissue from the Fort Devens section of the Nashua River. Cadmium concentrations in Nashua River fish are above the NCBP geometric mean

and 85th percentile. The levels of Cd, however, vary greatly among species and within species-specific samples from the Nashua River. No further action is recommended at this time other than continued monitoring within established programs.

Cadmium was detected in 3 bullhead fillets at a concentration of 0.02 : g/g, and it was undetected in bass fillets. Moore and Ramamoorthy (1984b) stated that some regulatory standards restrict consumption of fish with Cd residues in excess of 0.5 : g/g.

Chromium (Cr) -Trivalent Cr is an essential trace element for vertebrates. The hexavalent form of Cr, however, may cause adverse effects in the liver and kidney, and could also be a carcinogen (FDA 1993b, Environment Canada and Health Canada 1994). In the laboratory, Cr is a mutagen, carcinogen, and teratogen to several organisms (Eisler 1986b). Chromium bioaccumulates in fish gills, liver, and kidneys (Holdway 1988). In heavily contaminated areas, biota may accumulate high levels of Cr. Freshwater snails from the Sebasticook River in central Maine contained 22 to 440 : g Cr/g, dry weight (Duval *et al*. 1980).

Chromium was not included in the NCBP. Values reported in the scientific literature and field studies are presented for comparative purposes. Average Cr concentrations in freshwater fish muscle may be less than 0.25 : g/g (Moore and Ramamoorthy 1984b). Levels of Cr in fish from 14 Ontario lakes averaged 0.23 : g/g, with a range of 0.19 to 0.27 : g/g (Johnson 1987). In Maine (Sowles *et al*. 1997), Cr in wholebody fish of several species from 35 locations ranged from 0.04 to 0.84 : g/g. In a 1993-94 tissue study, wholebody largemouth bass, bullhead, and yellow perch from Reservoir #2 in the Sudbury River had Cr concentrations of 0.60 : g/g, 0.39 : g/g, and 1.13 : g/g, respectively (Haines *et al.* 1998). Reservoir #2 is immediately downstream from a Superfund Site. In 1989, the USFWS conducted fish tissue investigations in the Nashua River at the Oxbow National Wildlife Refuge, an area immediately upstream of the river reach at Fort Devens. Two white sucker and 1 yellow perch wholebody composite samples from that study had Cr concentrations of 2.55 : g/g, 1.21 : g/g, and 0.33 : g/g, respectively (USFWS, unpublished data). In 1992, reconstructed wholebody bass from Grove Pond in Ayer (Mierzykowski *et al.* 1993) had a geometric mean Cr concentration of 0.51 : g/g (range: 0.35 - 1.16 : g/g).

< The concentrations of chromium in Nashua River fish at Fort Devens, particularly in yellow perch, were elevated compared to the average concentration cited by Moore and Ramamoorthy (1984b), field data from Massachusetts Department of Environmental Protection and USFWS, and regional studies. The estimated mean Cr concentration in perch wholebody samples is 13.51 : g/g. Six of the 9 perch samples had Cr concentrations in excess of 4 : g/g and the highest sample had 44.63 : g Cr/g. Estimated mean Cr concentrations in bass and bullhead reconstructed wholebody sample are 0.70 : g/g and 0.82 : g/g, respectively.

It is difficult to evaluate the high Cr levels in yellow perch wholebody composite samples from the Fort Devens section of the Nashua River. Chromium levels are clearly elevated in sediments (max. 724

: g/g DW, Table 1) and well above the Cr sediment effect concentration of 270 : g/g DW (ER-M, Ingersoll *et al.* 1996). Ingested sediment remains in the gut may have influenced the perch Cr concentration during analysis. However, brown and yellow bullhead, bottom feeding omnivorous species that are regularly in direct contact with sediment, had lower Cr levels than perch. Diet may be a deciding factor in the dissimilar concentrations among the fish species. Mathis and Cummings (1973) reported that omnivorous fish generally have higher Cr concentrations than carnivores (e.g., bass). Yellow perch in the Fort Devens section of the Nashua River may be feeding on different macroinvertebrate species than bass or bullhead. Because Cr does not biomagnify in food chains, it is possible that macroinvertebrates in the Nashua River may have considerably higher concentrations of Cr than fish (Friant 1979, Holdway 1988). The presence of Cr in the Nashua River may have a greater direct impact on lower trophic levels than fish. Additional work in the river may be warranted.

Chromium was not detected in bass or bullhead fillets from the Nashua River and should not be a problem for anglers selecting those species. Whether Cr in yellow perch fillets would be a potential health problem for anglers is unknown. In a 1986 study conducted by the Massachusetts Department of Environmental Protection, composite samples of white sucker (*Catostomas commersoni*) fillets from the Nashua River contained Cr ranging from non-detect to 0.50 : g/g (Maietta 1986). In a study at a chromium-contaminated reservoir (Elwood *et al.* 1980), investigators found no significant difference between concentrations of Cr in largemouth bass and bluegill axial muscle (i.e., fillet) and wholebody tissue. Our Nashua River bass and bullhead samples were clearly different, and Cr was detected in carcasses rather than fillets. Based on our bass and bullhead results, we would not expect Cr to accumulate in perch fillets. However, there may be interspecific differences in Cr accumulation in fish and human health risk assessors should decide if Cr in yellow perch fillets warrant study.

Copper (Cu) - Copper is an essential element for vertebrates, and commonly found in fish tissue. Early life stages of salmonids are susceptible to waterborne Cu and teratogenic effects including lordosis, soliosis, kyphosis, and rigid coiling of the vertebral column (Birge and Black 1979) may result from exposure.

Freshwater fish can regulate Cu over a wide range of concentrations, but will accumulate copper in excess of nutritional requirements if continually exposed to the element (Leland and Kuwabara 1985). Moore and Ramamoorthy (1984b) suggested that even in polluted waters, fish muscle tissue concentrations seldom exceed 1 : g Cu/g. They also surmised that contaminated food is probably a more important source of copper than water. In New England, Cu concentrations above 1 : g/g in fish tissue are not unusual. In several USFWS field studies (unpublished data) in the region, Cu has been detected above 1 : g/g (range: 0.3 to 55 : g/g, wholebody) in several centrarchid and percid species in different watersheds.

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Cu concentration is 0.65 : g/g, the 85^{th} percentile is 1.0 : g/g, and the maximum is 23.1 : g/g. The highest concentration of Cu found in this study was in reconstructed wholebody bass samples (Θ_A 1.10 : g/g) followed by wholebody perch (Θ_A

1.04 : g/g) and reconstructed wholebody bullhead (Θ_A 0.99 : g/g). These concentrations are similar to results reported by Eaton and Carr (1991) in the Sudbury River drainage for wholebody composite samples of yellow perch (Θ_G 1.29 : g/g). In Grove Pond (Ayer, Massachusetts), Cu concentrations in reconstructed wholebody bass (Θ_G 0.46 : g/g), reconstructed bullhead (Θ_G 0.68 : g/g) and wholebody bluegill (Θ_G 0.58 : g/g) were lower than the Nashua River results.

< We do not consider the concentrations of Cu in fish tissue from the Fort Devens section of the Nashua River to be highly elevated. As noted above, Cu concentrations of 1 : g/g are not unusual in New England fish.

Copper concentrations in our fillets are not elevated compared to other Massachusetts studies. Copper was detected in all bass (Θ_G 0.34 : g/g, range: 0.17 - 0.85 : g/g) and bullhead (Θ_G 0.38 : g/g, range: 0.24 - 0.66 : g/g) fillets from the Fort Devens section of the Nashua River. In an earlier Nashua River study (Maietta 1986), white sucker fillets samples collected at 9 stations throughout the drainage contained Cu ranging from non-detect to 35 : g/g. At Grove Pond in Ayer, geometric mean concentrations in bass and bullhead fillets were 0.27 : g/g and 0.32 : g/g, respectively (Mierzykowski *et al.* 1993).

Mercury (Hg) - Mercury is a mutagen, teratogen, and carcinogen, which bioconcentrates in organisms and biomagnifies through food chains (Eisler 1987). Upper trophic level, long-lived, piscivorous fish species, such as bass (Stafford and Haines 1997) or species at the top of extended food chains (Cabana *et al.* 1994), typically have higher Hg concentrations than lower trophic species (Akielaszek and Haines 1981). Methylmercury, an organic form of mercury, is a potent neurotoxin that accounts for over 95% of the total Hg in adult fish tissue (Grieb *et al*. 1990). Mercury accumulates in the axial muscle tissue (i.e., fillet) of fish (Schmitt and Finger 1987). Wholebody concentrations of 1-5 : g Hg/g may have chronic effects in trout, while concentrations of 10-20 : g/g could be lethal (Niimi and Kissoon 1994). Piscivorous birds and mammals are also at risk from Hg in fish tissue. Barr (1986) reported that loons feeding on fish with Hg concentrations of 0.30 to 0.40 : g/g appeared to have impaired reproduction. Mercury can be lethal to mink at dietary concentrations of 1.1 : g/g (Kucera 1983) and to river otter (*Lutra canadensis*) at dietary concentration above 2 : g/g (O'Connor and Nielsen 1980).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Hg concentration is 0.10 : g/g and the 85th percentile was 0.37 : g/g. In reconstructed wholebody and wholebody samples from the Fort Devens section of the Nashua River, Hg is highest in bass (Θ_A 0.24 : g/g). The estimated mean Hg concentration in reconstructed wholebody bullhead is 0.20 : g/g, while yellow perch wholebody samples (Θ_A 0.16 : g/g, range 0.06 - 0.27 : g/g) have the lowest Hg concentration. Compared to another study in the area, Hg in bass reconstructed wholebody samples are not highly elevated. In Grove Pond (Ayer, Massachusetts), the mean Hg concentration in bass reconstructed wholebody samples was 0.32 : g/g (range: 0.10 - 1.13 : g/g; Mierzykowski *et al*. 1993). The concentration of Hg in reconstructed wholebody bullhead samples (Θ_G 0.04 : g/g) from Grove Pond, however, were considerably lower than the estimated mean concentration in bullhead reconstructed wholebody samples from the Fort Devens section of the Nashua River. Yellow perch in the Nashua River have Hg concentrations within the range of other Massachusetts rivers. In 1986, Hg in yellow perch wholebody composite samples from the Sudbury, Concord, and Assabet Rivers ranged from 0.17 to 0.37 : g/g (Eaton and Carr 1991). It should be noted that the Sudbury River is influenced by a Superfund Site in Ashland, Massachusetts, that deposited Hg to the river system for decades.

< Mercury is a potential contaminant of concern for piscivorous wildlife receptors in the Fort Devens section of the Nashua River. Eisler (1987) recommended a fish Hg concentration of 0.10 : g/g for the protection of sensitive piscivorous birds and mammals. The Hg levels in Nashua River fish exceed this protection limit. The reconstructed wholebody and wholebody Hg levels, however, are below the loon reproductive effect concentration suggested by Barr (1986). While the common loon has bred in the southern part of the Nashua River watershed at Wachusett Reservoir (Veit and Peterson 1993), other piscivores such as herons, kingfishers, and mergansers may be at risk from Hg in the watershed. Mercury is a widespread contaminant in New England. Nashua River Hg levels in fish tissue are elevated compared to recommended protection criteria, however, they are not unusually high for the region.

The FDA Action Level for mercury in fish is 1.0 : g/g (FDA 1992). Several states have adopted lower action levels for the protection of human health. Maine, for example, has a fish consumption advisory threshold level of 0.43 : g Hg/g (Maine Department of Human Services 1997). Due to widespread Hg contamination in United States freshwater fish, several states have expanded consumption advisories and warned vulnerable receptor groups such as pregnant women and children to avoid eating any fish from many lakes and rivers (EPA 1995). Mercury was detected below the FDA action level in all bass (θ_G 0.33 : g/g, range: 0.21 - 0.61 : g/g) and bullhead (θ_G 0.26 : g/g, range: 0.07 - 0.69 : g/g) fillets from the Fort Devens section of the Nashua River. However, without a site-specific evaluation by human health risk assessors, it would be inappropriate to assume that fish from the river reaches documented here are safe for human consumers. The Hg levels in bass and bullhead fillets from the Fort Devens section of the Nashua River are not unusual compared to other State data. Bass and bullhead fillets from 24 waterbodies in three different ecological subregions in Massachusetts had average Hg concentrations of 0.40 : g/g (range: 0.05 - 1.1 : g/g) and 0.14 : g/g (range: 0.01 - 0.79 : g/g), respectively (MADEP 1997).

Nickel (Ni) - Relatively little information regarding the effects of elevated Ni body burdens on fish and wildlife is available. Nickel does not concentrate through the food chain (Moore and Ramamoorthy 1984b). However, Ni occurring in the tissues of some piscivorous bird species may reflect metal concentrations in prey items. For example, Custer *et al.* (1986) in a Rhode Island study of common terns (*Sterna hirundo*) found the highest Ni concentrations in tern liver tissue (up to 0.25 : g/g) where the main prey item, killifish (*Fundulus* spp.), also had the highest Ni concentration (0.52 : g/g). Outridge and Scheuhammer (1993) suggested that mammals and birds may have the ability to regulate Ni assimilation at dietary concentrations up to 25 : g/g. They also reported that chronic Ni exposure at dietary concentrations of 10 - 50 mg/kg body weight/day may reduce growth and survival in mammals.

Nickel was not included in the NCBP. Jenkins (1980) suggested a preliminary estimate of Ni in freshwater fish from uncontaminated areas of < 0.2 to 2.0 : g/g, but cautioned that more data were needed. In other Massachusetts fish tissue studies, Ni has been detected at concentrations within this range. In Grove Pond, Ayer (MA), reconstructed wholebody bass and bullhead had geometric mean Ni concentrations of 0.19 : g/g and 0.18 : g/g, respectively (Mierzykowski *et al.* 1993). In 1989, 2 white sucker wholebody composite samples and 1 yellow perch wholebody composite sample collected from the Nashua River at the Oxbow National Wildlife Refuge, immediate upstream of the Fort Devens study area, contained Ni concentrations of 1.51 : g/g, 0.53 : g/g, and 0.09 : g/g (USFWS, unpublished data).

Bone often contains higher Ni concentrations than other tissue (Outridge and Scheuhammer 1993), and fish carcass samples reflect this partitioning. In the Fort Devens section of the Nashua River, Ni was detected in 8 of the 24 carcass and wholebody samples, and in none of the fillet samples. In 3 reconstructed wholebody bullhead, the detectable Ni concentrations range from 0.11 to 0.19 : g/g. Nickel concentrations are more variable in perch samples. The maximum Ni concentration is 0.65 : g/g in yellow perch wholebody sample (SDP1-YwP-4), and the estimated mean for all yellow perch is 0.26 : g/g.

< Tissue concentrations of Ni in Nashua River fish are within the range suggested by Jenkins (1980) and below the wildife receptor assimilation range reported by Outridge and Scheuhammer (1993). Consequently, we would not expect Ni to be a contaminant of concern to wildlife receptors in the Fort Devens section of the Nashua River.

As noted above, Ni was not detected in bass or bullhead fillets.

Lead (Pb) -Lead is an ubiquitous environmental contaminant that is commonly found in fish and wildlife tissues, particularly in species with habitats proximal to roads and urban or industrial developments. Lead is bioconcentrated, but does not appear to magnify through food chains (Eisler 1988). Exposure to Pb may cause neurological effects, kidney disfunction, and anemia in vertebrates (Leland and Kuwabara 1985). Lead is known to inhibit *-aminolevulinic acid dehydratase (ALAD) activity, an enzyme necessary for hemoglobin synthesis, and to elevate protoporphyrin concentrations (Henny *et al.* 1991). Adverse Pb effects on aquatic biota can include reduced survival, impaired reproduction, impaired function of the liver, kidney, and spleen, reduced growth, and spinal deformities (Holcombe *et al.* 1976, Eisler 1988). Lead accumulation varies among fish species, and concentrations do not appear to be related to size (Czarnezki 1985). Lead is concentrated at higher levels in calcified or hard tissue (i.e., bone, skin, scales) than in muscle and other soft tissues (Patterson and Settle 1976). Because Pb is more likely to accumulate in bone, Pb exposure may be limited by piscivorous birds that cast pellets containing partially digested or undigested bone of their prey (Henny *et al.* 1994).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Pb concentration is 0.11 :g/g and the 85th percentile is 0.22 :g/g. Compared to the NCBP, Pb levels in Nashua River fish are elevated in reconstructed wholebody bullhead (Θ_A 0.59 :g/g) and yellow perch wholebody samples (Θ_A 1.06 :g/g). Lead was detected in only three reconstructed wholebody bass (range: 0.29 - 0.45 :g/g). In a 1989 study (USFWS, unpublished data) of the Nashua River at the Oxbow National Wildlife Refuge, composite samples of white sucker and yellow perch contained Pb concentrations of 0.48 :g/g and 0.94 :g/g, respectively. In a study of the Sudbury River system, Haines *et al*. (1998) found the highest Pb concentrations, 0.22 :g/g, in yellow perch collected from their study reference area, Whitehall Reservoir in Hopkinton (Massachusetts). The levels in the Nashua River, however, are not highly elevated compared to grossly contaminated areas. In the Coeur d'Alene River in Idaho, highly elevated concentrations of Pb were reported in bullhead (21.6 :g/g) and yellow perch (3.1 :g/g) whole fish composite samples, while largemouth bass had a mean Pb concentration of 0.75 :g/g (Henny *et al*. 1991).

< Lead may be a potential a contaminant of concern in the Fort Devens section of the Nashua River. Compared to other studies, Pb in tissue is elevated in Nashua River fish. Continued monitoring of this contaminant within established programs is recommended.

There is no FDA Action Level for Pb in fish tissue, but a concentration of 0.3 :g/g has been developed by the World Health Organization as an upper permissible limit for Pb in foods (Settle and Patterson 1980). Lead was not detected in bass or bullhead fillets. In an earlier Nashua River study, Maietta (1986) found Pb in white sucker fillet composite samples ranging from non-detect to 5.3 :g/g.

Selenium (Se) - Selenium contamination in drainwater and surface water is a serious problem to fish and wildlife resources in the western United States, a region with seleniferous soils. In the eastern United States seleniferous soils are less common, but Se has been identified in the Northeast as an environmental contaminant in fish collected from rivers in industrialized areas. Selenium is an essential trace element for vertebrates. Nominal dietary intake of Se by rainbow trout (*Oncorhynchus mykiss*) is approximately 0.07 :g/g (Hilton *et al*. 1980). Selenium may cause death in deficient amounts (Eisler 1985b). Elevated intake of Se can also be harmful. Fish consuming diets with 10 to 33 :g Se/g have experienced toxic effects (Hilton *et al*. 1980, Besser *et al*. 1993). Excessive amounts may be lethal, cause reproductive abnormalities or failure, result in tissue damage, retard growth, or eliminate entire fish communities (Eisler 1985b, Lemly 1996). In one study, bluegill with tissue concentrations of 7.94 :g Se/g had reproductive problems (Gillespie and Baumann 1986). Reproductive effects or mortality may occur in fish and waterfowl foraging on prey items with Se concentrations ranging from 0.75 to 1.25 :g/g (Lemly and Smith 1987).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Se concentration is 0.42 :g/g and the 85th percentile is 0.73 :g/g. In various parts of the Great Lakes, Hodson (1990) reported that whole fish generally had Se concentrations less than 1 :g/g (range: 0.10 - 1.55 :g/g). Selenium was detected in all fish tissue samples from the Fort Devens section of the Nashua River. The estimated mean Se concentrations in reconstructed wholebody bass (Θ_A 0.54 : g/g) and bullhead (Θ_A 0.44 : g/g) are above the NCBP geometric mean, but below the 85th percentile. Yellow perch wholebody samples have an estimated mean Se concentration of 0.86 : g/g, a level slightly above the NCBP 85th percentile.

< Selenium is a potential contaminant of concern for piscivores in the Fort Devens section of the Nashua River. The Se concentrations in fish tissue are within the range suggested by Lemly and Smith (1987) to possibly cause reproductive effects in fish and wildlife. The levels in Nashua River fish, however, are not highly elevated and no further action is recommended at this time except continued monitoring within established programs.

Selenium concentrations exceeding 1 : g/g in fish tissue may be a problem for human consumers (Fan *et al.* 1988). In the Fort Devens section of the Nashua River, Se was detected in all bass (Θ_G 0.56 : g/g, range: 0.39 - 0.87 : g/g) and bullhead (Θ_G 0.29 : g/g, range: 0.20 - 0.42 : g/g) fillets. Data from two ponds associated with the Nashua River indicate the Se fillet level in the Fort Devens section of the Nashua River may be elevated, particularly in bass. Bass fillets collected from Pepperell Pond in Pepperell, Massachusetts, in 1993 had a mean Se concentration of 0.27 : g/g (Nuzzo *et al.* 1997). Bass and bullhead fillets collected from Grove Pond in Ayer, Massachusetts, in 1992 had mean Se concentrations of 0.16 : g/g and 0.07 : g/g, respectively (Mierzykowski *et al*. 1993).

Zinc (Zn) - Zinc is an essential element for vertebrates. Although it is an uncommon occurrence in aquatic systems, fish with diets deficient in Zn can experience reduced growth and increased mortality (Spry *et al*. 1988). Generally, Zn is efficiently regulated by wildlife and tissue concentrations are not reliable indicators of exposure (Beyer and Storm 1995). Spry *et al*. (1988) found no toxic effects in rainbow trout from exposure to high dietary and waterborne concentrations of Zn based on growth, mortality, major plasma ions, hematocrit, or plasma protein. However, Eisler (1993) reported that elevated concentrations of waterborne Zn has adverse effects on growth, survival, behavior, and reproduction of sensitive fish, with early life stages being the most sensitive.

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Zn concentration is 21.7 : g/g and the 85th percentile is 34.2 : g/g. In a study of Cd and Zn from an industrially contaminated lake, Murphy *et al.* (1978) reported Zn concentrations ranging from 34.7 to 56.2 : g/g and 19.7 to 29.7 : g/g for bluegill and largemouth bass, respectively. Citing several sources, Murphy *et al*. (1978) reported average Zn whole fish concentrations from uncontaminated areas ranging from 12 to 43 : g/g. Zinc concentrations in fish from the Fort Devens section of the Nashua River are not highly elevated compared to the NCBP and Murphy *et al.* (1978). The estimated mean concentration of Zn in reconstructed wholebody bass is 20.42 : g/g (range: 14.25 - 24.15 : g/g), while in yellow perch wholebody samples the range is 17.98 - 30.66 : g/g (Θ_A 22.45 : g/g). The highest Zn concentration was found in bullhead reconstructed wholebody sample SDP1-BBH-5C (34.93 : g/g), but the estimated mean for reconstructed wholebody bullhead (Θ_A 23.39 : g/g) and range are not extraordinary.

< Zinc concentrations in fish from the Fort Devens section of the Nashua River are not highly elevated and should not pose a potential risk to ecological receptors.

Zinc was detected in all bass (Θ_G 6.23 : g/g, range: 3.79 - 9.14 : g/g) and bullhead (Θ_G 7.48 : g/g, range: 4.14 - 10.84 : g/g) fillets. Compared to an earlier Nashua River study, Zn concentrations in fillets do not appear unusual. Maietta (1986) analyzed white sucker fillet composites from 9 locations throughout the Nashua River and found Zn concentrations ranging from non-detect to 24 : g/g.

SUMMARY

Sediments and fish from the portion of the Nashua River passing through Fort Devens contain elevated concentrations of several organochlorine and trace element contaminants. Some of these contaminants may pose a risk to ecological receptors (potential risks to human consumers of Nashua River fish are not addressed in this report). In analyses of wholebody yellow perch and reconstructed wholebody largemouth bass and bullhead; yellow perch had the highest concentrations of PCBs, DDT, chlordane, dieldrin, chromium, nickel, lead, and selenium. Reconstructed wholebody bass had the highest concentrations of copper, and mercury, while cadmium and zinc were highest in reconstructed wholebody bullhead.

The contaminants that may pose the greatest potential risk to wildlife receptors consuming fish from the Nashua River include PCBs, DDT, and mercury. Chromium levels were also highly elevated in yellow perch, and may warrant further study. Contaminants that were elevated and may require further monitoring within established programs (e.g., Massachusetts Department of Environmental Protection's Fish Toxics Monitoring Program) include arsenic, cadmium, lead, and selenium. Contaminants probably requiring no further action include dieldrin, copper, nickel, and zinc.

Large differences in contaminant concentrations were found among the three trophic levels represented by the fish species included in this study. These differences may be related to the trophic status, foraging preferences, or movement patterns of the fish species.

A separate evaluation of the contaminant concentrations in fish from the Fort Devens section of the Nashua River by human health risk assessors is recommended. Specifically, PCBs, chromium, and lead in yellow perch muscle tissue may require further study. Some anglers eat more than the fillet or muscle portion of fish. Based on fish carcass and wholebody analytical results, receptor groups that consume fish organ tissue or use the entire fish in meals may be at greater risk from some contaminants.

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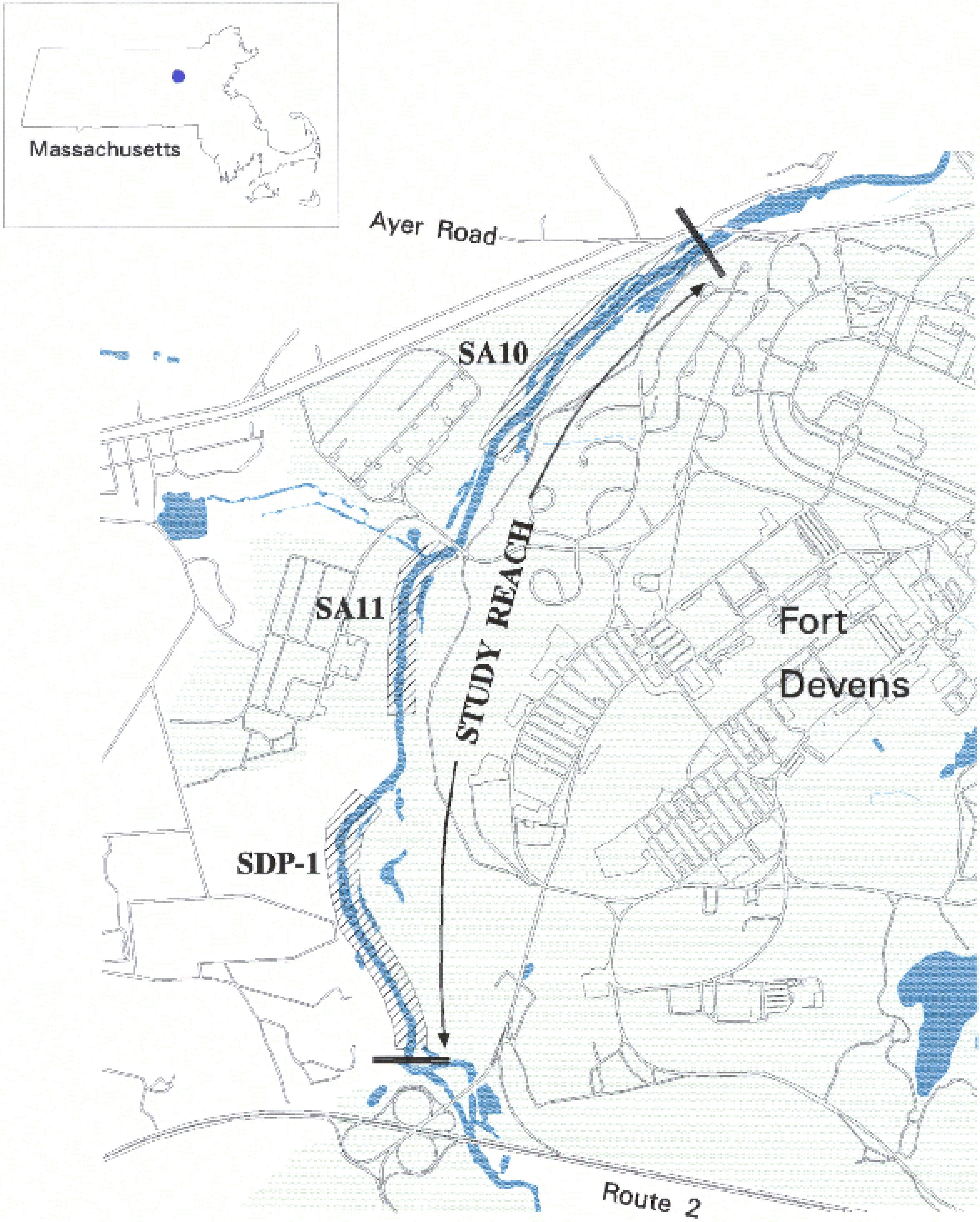
FIGURES

Figure 1. Fort Devens and Nashua River fish collection locations (adapted from MADEP data).



Collection Locations:

SDP-1
SA11
SA10

Scale 1:24000

1 .5 0 1 KILOMETER

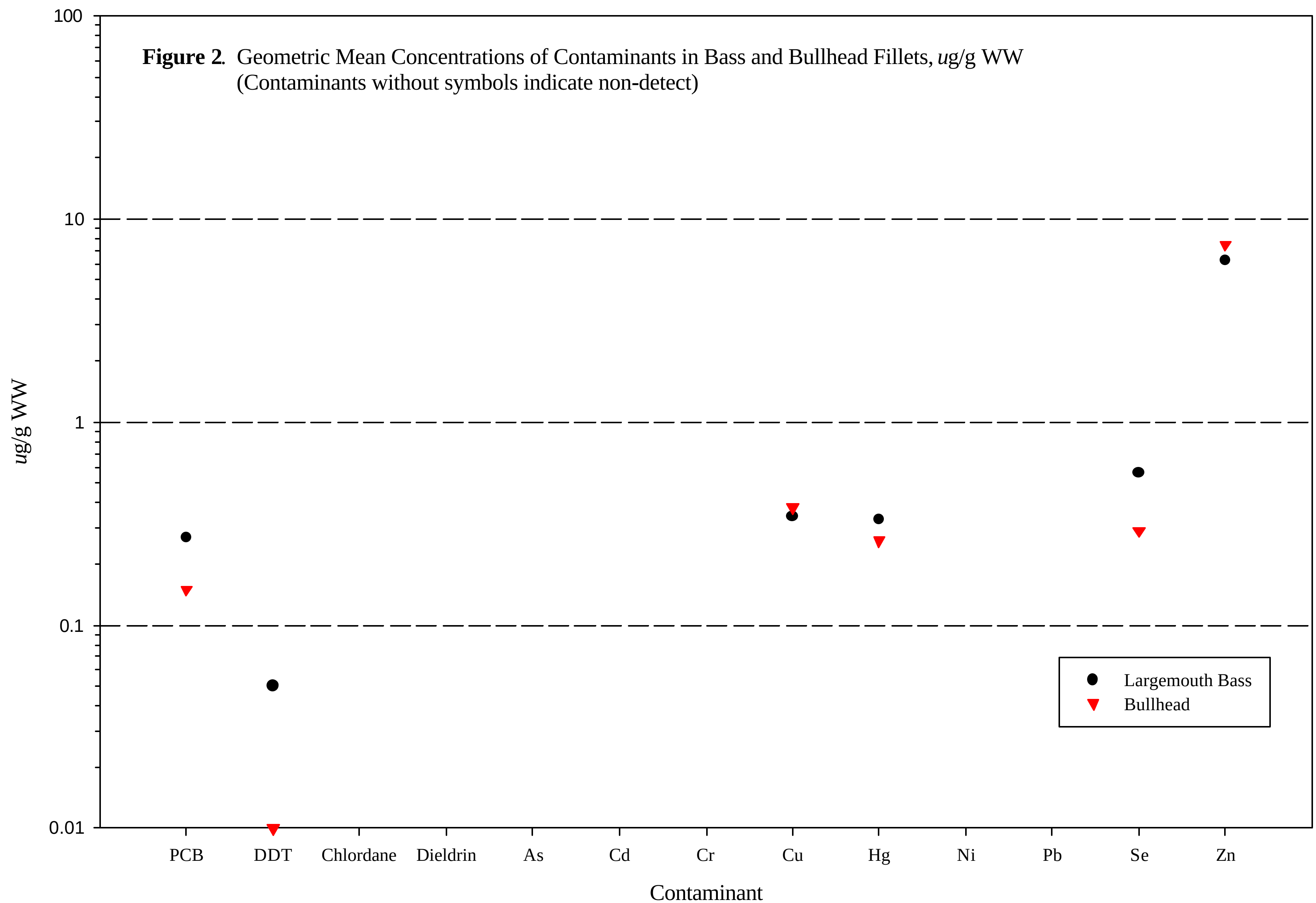


Figure 2. Geometric Mean Concentrations of Contaminants in Bass and Bullhead Fillets, *u*g/g WW
(Contaminants without symbols indicate non-detect)
100
10
1
0.1
0.01
*u*g/g WW
PCB
DDT
Chlordane
Dieldrin
As
Cd
Cr
Cu
Hg
Ni
Pb
Se
Zn
Contaminant
Largemouth Bass
Bullhead

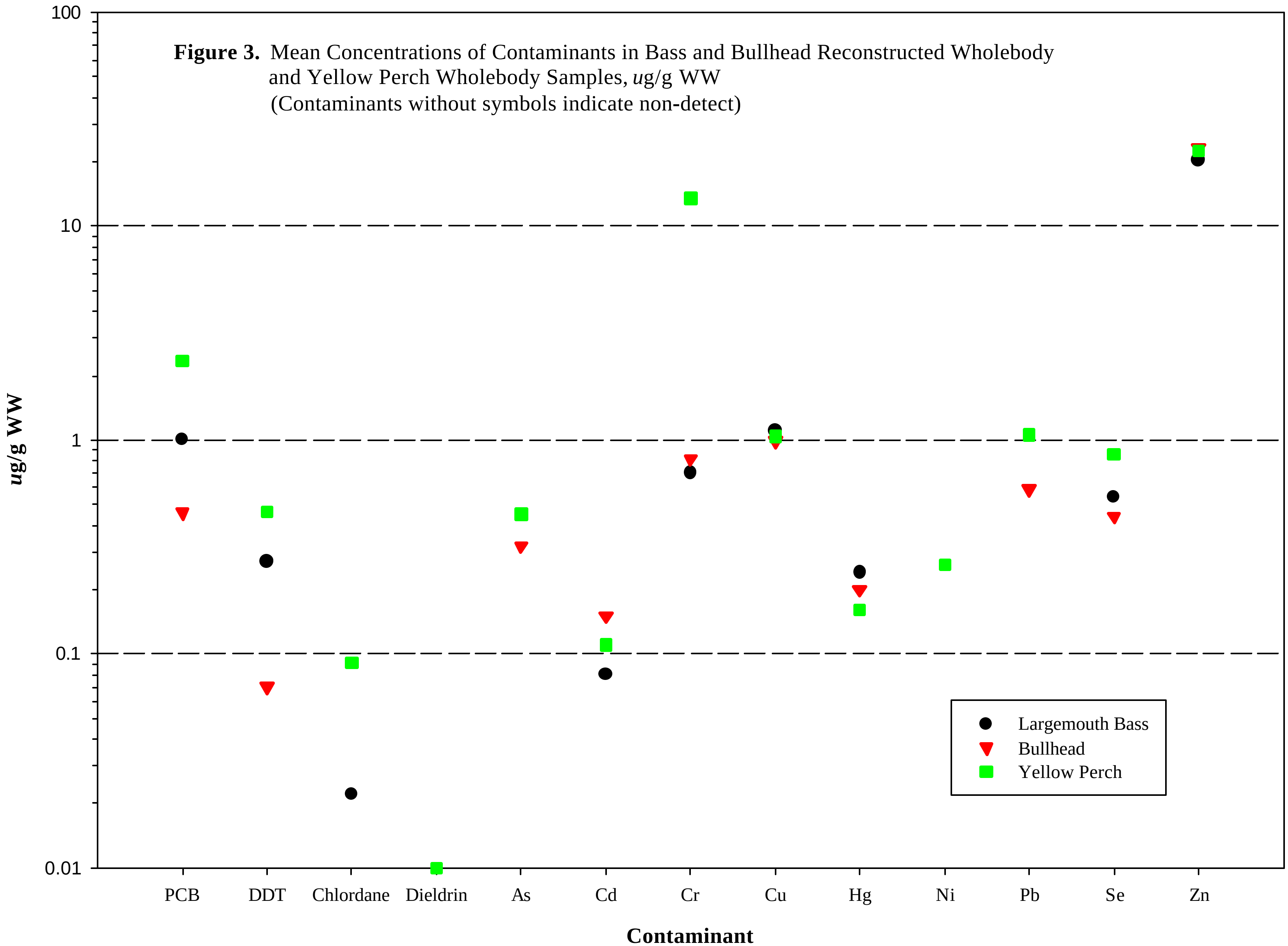


Figure 3. Mean Concentrations of Contaminants in Bass and Bullhead Reconstructed Wholebody
and Yellow Perch Wholebody Samples, ug/g WW
(Contaminants without symbols indicate non-detect)
100
10
1
0.1
0.01
ug/g WW
PCB
DDT
Chlordane
Dieldrin
As
Cd
Cr
Cu
Hg
Ni
Pb
Se
Zn
Contaminant
Largemouth Bass
Bullhead
Yellow Perch

TABLES

Table 1. Maximum Concentrations of Environmental Contaminants in Nashua River **Sediments** by Reach, *u* g/g DW.

Contaminant	Reach			Sediment Effect Concentrations	
	SDP1	SA11	SA10	ER-L	ER-M
As	41.40	11.20	19.60	13	50
Cd	59.20	303.00	124.00	0.7	3.9
Cr	724.00	435.00	348.00	39	270
Cu	1100.00	470.00	460.00	41	190
Hg	10.00	11.00	15.00	0.15	1.3**a**
Ni	221.00	45.70	26.20	24	45
Pb	1400.00	760.00	740.00	55	99
Se	nd	28.10	9.81	na	na
Zn	1690.00	724.00	642.00	110	550
PCB-Total	0.31	0.92	0.59	0.05	0.73
DDT-Total	0.05	0.21	0.54	0.117	0.35**a**

nd = not detected, na = not available
Sediment data from A.D. Little, Inc. (1993) and A.D. Little, Inc. (1995)
Sediment Effect Concentrations from Ingersoll et al.(1996); SECs followed by an **"a"** from Long and Morgan (1991)
Effect Range-Low (ER-L) was defined by Long and Morgan (1991) as the conc. below which effects from chemicals in sediment were rarely observed, while Effect Range-Median (ER-M) indicated a conc. where effects are frequently or always observed among most benthic species.
Shaded values indicate exceedance of ER-M

Table 2. Lengths and Weights of Fish (Arithmetic Mean and Standard Deviation).

Species	N	Length (cm)		Weight (g)	
		Mean	SD	Mean	SD
Largemouth Bass	16	29.7	4.70	455	256.15
Brown Bullhead	5	24.3	3.24	189	100.83
Yellow Bullhead	7	23.4	1.30	186	36.59
Yellow Perch	15	25.6	1.18	220	41.09

Table 3. Lengths and weights of individual fish by species.

Fish No.	Species	Total Length (cm)	Total Weight (g)
SDP1-LmB-1	Largemouth bass	27.7	294
SDP1-LmB-2	Largemouth bass	36.2	895
SDP1-LmB-3	Largemouth bass	36.3	972
SDP1-LmB-4	Largemouth bass	28.6	351
SDP1-LmB-5	Largemouth bass	26.5	282
SA11-LmB-1	Largemouth bass	37.0	800
SA11-LmB-2	Largemouth bass	29.5	423
SA11-LmB-3	Largemouth bass	25.6	261
SA11-LmB-4	Largemouth bass	25.5	201
SA11-LmB-5	Largemouth bass	29.8	358
SA10-LmB-1	Largemouth bass	29.1	444
SA10-LmB-2	Largemouth bass	26.9	313
SA10-LmB-3	Largemouth bass	20.0	131
SA10-LmB-4	Largemouth bass	34.5	667
SA10-LmB-5	Largemouth bass	33.5	606
SA10-LmB-6	Largemouth bass	28.2	276
SDP1-BBH-1	Brown bullhead	22.7	161
SDP1-BBH-2	Brown bullhead	25.8	211
SA10-BBH-1	Brown bullhead	19.7	101
SA10-BBH-2	Brown bullhead	25.2	120
SA10-BBH-3	Brown bullhead	28.2	353
SDP1-YBH-3	Yellow bullhead	24.7	204
SDP1-YBH-4	Yellow bullhead	23.0	165
SA11-YBH-1	Yellow bullhead	25.0	241
SA11-YBH-2	Yellow bullhead	22.8	160
SA11-YBH-3	Yellow bullhead	24.3	223
SA11-YBH-4	Yellow bullhead	22.4	160
SA11-YBH-5	Yellow bullhead	21.5	147
SDP1-YwP-1	Yellow perch	25.5	198
SDP1-YwP-2	Yellow perch	26.4	236
SDP1-YwP-3	Yellow perch	27.3	290
SDP1-YwP-4	Yellow perch	23.8	172
SDP1-YwP-5	Yellow perch	25.7	197
SA11-YwP-1	Yellow perch	27.1	299
SA11-YwP-2	Yellow perch	25.7	201
SA11-YwP-3	Yellow perch	24.6	171
SA11-YwP-4	Yellow perch	24.7	198
SA11-YwP-5	Yellow perch	23.5	169
SA10-YwP-1	Yellow perch	26.6	262
SA10-YwP-2	Yellow perch	27.0	240
SA10-YwP-3	Yellow perch	25.7	242
SA10-YwP-4	Yellow perch	25.6	225
SA10-YwP-5	Yellow perch	24.5	200

Table 4. Sample descriptions - **Largemouth bass**, Bullhead, Yellow perch.

Sample No.	Sample Weight (g)	Matrix
SDP1-LmB-1F	58	Fillet
SDP1-LmB-2F	132	Fillet
SDP1-LmB-3F	155	Fillet
SDP1-LmB-4F	55	Fillet
SDP1-LmB-5F	56	Fillet
SDP1-LmB-6C	758	Carcass composite[1]
SDP1-LmB-7C	1580	Carcass composite[2]

[1] Composite of carcass samples SDP1-LmB-1C, SDP1-LmB-4C, and SDP1-LmB-5C
[2] Composite of carcass samples SDP1-LmB-2C and SDP1-LmB-3C

SA11-LmB-1F	89	Fillet
SA11-LmB-2F	62	Fillet
SA11-LmB-3F	64	Fillet
SA11-LmB-4F	76	Fillet
SA11-LmB-5F	67	Fillet
SA11-LmB-1C	711	Carcass
SA11-LmB-6C	652	Carcass composite[3]
SA11-LmB-7C	322	Carcass composite[4]

[3] Composite of carcass samples SA11-LmB-2C and SA11-LmB-5C
[4] Composite of carcass samples SA11-LmB-3C and SA11-LmB-4C

SA10-LmB-1F	62	Fillet
SA10-LmB-2F	80	Fillet
SA10-LmB-3F	35	Fillet
SA10-LmB-4F	96	Fillet
SA10-LmB-5F	124	Fillet
SA10-LmB-6F	88	Fillet
SA10-LmB-1C	382	Carcass
SA10-LmB-3C	96	Carcass
SA10-LmB-7C	421	Carcass composite[5]
SA10-LmB-8C	1053	Carcass composite[6]

[5] Composite of carcass samples SA10-LmB-2C and SA10-LmB-6C
[6] Composite of carcass samples SA10-LmB-4C and SA10-LmB-5C

Table 4 (cont'd). Sample descriptions - Largemouth bass, **Bullhead**, Yellow perch.

Sample No.	Sample Weight (g)	Matrix
SDP1-BBH-1F	38	Fillet
SDP1-BBH-2F	51	Fillet
SDP1-YBH-3F	50	Fillet
SDP1-YBH-4F	40	Fillet
SDP1-BBH-5C	283	Carcass composite[7]
SDP1-YBH-6C	279	Carcass composite[8]

[7] Composite of carcass samples SDP1-BBH-1C and SDP1-BBH-2C
[8] Composite of carcass samples SDP1-YBH-3C and SDP1-YBH-4C

SA11-YBH-1F	58	Fillet
SA11-YBH-2F	42	Fillet
SA11-YBH-3F	50	Fillet
SA11-YBH-4F	41	Fillet
SA11-YBH-5F	34	Fillet
SA11-YBH-6C	706	Carcass composite[9]

[9] Composite of carcass samples SA11-YBH-1C, 2C, 3C, 4C, and 5C.

SA10-BBH-1F	26	Fillet
SA10-BBH-2F	45	Fillet
SA10-BBH-3F	45	Fillet
SA10-BBH-1C	75	Carcass
SA10-BBH-2C	75	Carcass
SA10-BBH-3C	308	Carcass

BBH = Brown bullhead
YBP = Yellow bullhead

Table 4 (cont'd). Sample descriptions - Largemouth bass, Bullhead, **Yellow perch**.

Sample No.	Sample Weight (g)	Matrix
SDP1-YwP-4W	172	Wholebody
SDP1-YwP-6C	395	Wholebody composite[10]
SDP1-YwP-7C	526	Wholebody composite[11]

[10] Composite of wholebody samples SDP1-YwP-1W and SDP1-YwP-5W
[11] Composite of wholebody samples SDP1-YwP-2W and SDP1-YwP-3W

SA11-YwP-1W	299	Wholebody
SA11-YwP-6C	399	Wholebody composite[12]
SA11-YwP-7C	340	Wholebody composite[13]

[12] Composite of wholebody samples SA11-YwP-2W and SA11-YwP-4W
[13] Composite of wholebody samples SA11-YwP-3W and SA11-YwP-5W

SA10-YwP-1W	262	Wholebody
SA10-YwP-6C	482	Wholebody composite[14]
SA10-YwP-7C	425	Wholebody composite[15]

[14] Composite of wholebody samples SA10-YwP-2W and SA10-YwP-3W
[15] Composite of wholebody samples SA10-YwP-4W and SA10-YwP-5W

Reconstruction equation for bass and bullhead composites.

$$\mathbf{RWC_x = [\sum_{i}^{n} (FW_i * FC_{ix}) + (CW_t * CC_x)] / (\sum_{i}^{n} FW_i) + (CW_t)}$$

Where

- **FW_i is the fillet weight (samples $_{i\text{--}n}$)**
- **FC_{ix} is the concentration of contaminant $_x$ in fillet samples $_{i\text{--}n}$**
- **CW_t is the total weight of the carcass composite sample**
- **CC_x is the carcass concentration of contaminant $_x$, and**
- **RWC_x is the reconstructed wholebody concentration of contaminant $_x$**

Table 5. Summary of Contaminant Concentrations in Nashua River Fish, *u* g/g WW.

Contaminant	Largemouth Bass				Bullhead				Yellow Perch	
	Fillet (n=16)		Reconstructed Wholebody (n=9)		Fillet (n=12)		Reconstructed Wholebody (n=6)		Wholebody (n=9)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
PCB	0.27	nd-1.08	1.01	0.66-1.73	0.15	nd-0.67	0.46	0.29-0.60	2.35	1.52-3.28
DDT	0.05	nd-0.23	0.27	0.10-0.50	0.01	nd-0.06	0.07	0.03-0.14	0.46	0.26-0.70
Chlordane	nc	nd-0.013	0.022	nd-0.054	nd	nd	nc	nd-0.0126	0.091	0.040-0.153
Dieldrin	nd	nd	nc	nd-0.01	nd	nd	nd	nd	0.01	nd-0.016
As	nc	nd-0.21	0.45	0.14-0.93	nc	nd-0.35	0.32	0.11-0.81	0.45	0.19-0.95
Cd	nd	nd	0.08	0.04-0.11	nc	nd-0.02	0.15	0.03-0.23	0.11	0.08-0.16
Cr	nd	nd	0.70	0.52-0.99	nd	nd	0.82	0.44-1.76	13.51	0.89-44.63
Cu	0.34	0.17-0.85	1.10	0.56-1.82	0.38	0.24-0.66	0.99	0.51-1.93	1.04	0.57-1.91
Hg	0.33	0.21-0.61	0.24	0.15-0.46	0.26	0.07-0.69	0.20	0.05-0.49	0.16	0.06-0.27
Ni	nd	nd	nd	nd	nd	nd	nc	nd-0.19	0.26	nd-0.65
Pb	nd	nd	nc	nd-0.45	nd	nd	0.59	nd-1.11	1.06	0.57-1.55
Se	0.56	0.39-0.87	0.54	0.43-0.69	0.29	0.20-0.42	0.44	0.29-0.64	0.86	0.54-1.20
Zn	6.23	3.79-9.34	20.42	14.25-24.15	7.48	4.14-10.84	23.39	19.61-34.93	22.45	17.98-30.66

nd = non-detect, nc = not calculated. A mean was not calculated if one-half or more samples were non-detects.

Means for fillets are geometric. Means for reconstructed wholebody and wholebody are arithmetic.

Table 6. PCBs and DDT in **FILLET** samples of **BASS** from the Nashua River, *u* g/g WW.

Fish No.	Aroclor 1248	Aroclor 1254	Aroclor 1260	Total PCB	o,p' DDD	p,p' DDD	p,p' DDE	p,p' DDT	Total DDT
SDP1-LmB-1	0.05	0.08	nd	0.13	nd	nd	0.01	nd	0.01
SDP1-LmB-2	0.31	0.25	0.17	0.73	nd	0.05	0.05	nd	0.10
SDP1-LmB-3	0.07	0.08	nd	0.15	nd	0.01	0.02	nd	0.03
SDP1-LmB-4	0.34	0.27	0.14	0.75	0.02	0.10	0.09	0.02	0.23
SDP1-LmB-5	0.14	0.11	nd	0.25	nd	0.01	0.01	nd	0.02
SA11-LmB-1	0.18	0.10	nd	0.28	nd	0.03	0.02	nd	0.05
SA11-LmB-2	0.08	nd	nd	0.08	nd	0.03	0.02	0.01	0.06
SA11-LmB-3	0.25	0.19	0.14	0.58	0.01	0.07	0.05	0.01	0.14
SA11-LmB-4	0.74	0.08	nd	0.82	nd	0.01	0.01	nd	0.02
SA11-LmB-5	0.28	0.15	0.07	0.50	nd	0.03	0.03	nd	0.06
SA10-LmB-1	0.05	0.07	nd	0.12	nd	nd	nd	nd	0.005
SA10-LmB-2	nd	nd	nd	0.025	nd	0.01	0.01	nd	0.02
SA10-LmB-3	nd	nd	nd	0.025	nd	0.01	nd	0.01	0.02
SA10-LmB-4	0.45	0.41	0.22	1.08	0.01	0.07	0.06	0.03	0.17
SA10-LmB-5	0.38	0.26	0.14	0.78	0.01	0.07	0.06	0.04	0.18
SA10-LmB-6	0.56	0.29	0.16	1.01	0.01	0.07	0.06	0.01	0.15
n=16									
Geometric Mean	nc	nc	nc	0.27	nc	nc	nc	nc	0.05
SE	nc	nc	nc	0.092	nc	nc	nc	nc	0.018

nd = non-detect, nc = not calculated

For non-detects, one-half the method detection limit (shaded cells) was used to calculate the geometric means of Total PCB and Total DDT.

Table 7. PCBs and DDT in **RECONSTRUCTED WHOLEBODY BASS** from the Nashua River, *u* g/g WW.

Sample No.	Aroclor 1248	Aroclor 1254	Aroclor 1260	Total PCB	o,p' DDD	o,p' DDT	p,p' DDD	p,p' DDE	p,p' DDT	Total DDT
SDP1-LmB-6C	0.43	0.34	0.18	0.95	0.016	nd	0.081	0.089	0.010	0.20
SDP1-LmB-7C	0.54	0.45	0.29	1.28	0.013	nd	0.089	0.107	0.014	0.22
SA11-LmB-1	0.62	0.39	0.22	1.24	0.033	nd	0.225	0.216	0.023	0.50
SA11-LmB-6C	0.42	0.24	0.16	0.82	0.013	nd	0.089	0.070	0.029	0.20
SA11-LmB-7C	0.37	0.21	0.16	0.74	0.013	nd	0.070	0.052	0.010	0.14
SA10-LmB-1	0.45	0.32	0.19	0.96	0.016	nd	0.077	0.078	0.011	0.18
SA10-LmB-3	0.28	0.24	0.15	0.66	0.026	nd	0.179	0.104	0.193	0.50
SA10-LmB-7C	0.40	0.20	0.11	0.72	0.006	nd	0.049	0.042	0.011	0.10
SA10-LmB-8C	0.75	0.62	0.36	1.73	0.026	0.014	0.153	0.134	0.076	0.40
n=9										
Arithmetic Mean*	0.47	0.34	0.20	1.01	0.018	nc	0.112	0.099	0.042	0.27

* The mean should be considered an estimate because some samples were composites.
Sample numbers ending in "C" indicate a composite.

nd = non-detect, nc = not calculated

Table 8. PCBs and DDT in **FILLET** samples of **BULLHEAD** from the Nashua River, *u* g/g WW.

Fish No.	Aroclor 1248	Aroclor 1254	Aroclor 1260	Total PCB	p,p' DDD	p,p' DDE	p,p' DDT	Total DDT
SDP1-BBH-1F	0.19	nd	nd	0.19	0.02	0.02	nd	0.04
SDP1-BBH-2F	0.19	0.10	0.07	0.36	0.02	0.01	nd	0.03
SDP1-YBH-3F	nd	nd	nd	0.025	nd	nd	nd	0.005
SDP1-YBH-4F	nd	0.06	nd	0.06	nd	nd	nd	0.005
SA11-YBH-1F	nd	0.06	0.09	0.15	nd	nd	nd	0.005
SA11-YBH-2F	nd	0.09	nd	0.09	0.01	nd	nd	0.01
SA11-YBH-3F	nd	nd	0.09	0.09	0.02	nd	nd	0.02
SA11-YBH-4F	0.10	0.07	0.08	0.24	0.02	0.01	nd	0.03
SA11-YBH-5F	0.07	0.06	nd	0.14	nd	nd	nd	0.005
SA10-BBH-1F	0.07	0.10	nd	0.17	0.02	nd	nd	0.02
SA10-BBH-2F	0.10	0.12	nd	0.20	0.04	0.03	nd	0.06
SA10-BBH-3F	nd	0.67	nd	0.67	nd	nd	nd	0.005
n=12								
Geometric Mean	nc	nc	nc	0.15	nc	nc	nd	0.01
SE	nc	nc	nc	0.050	nc	nc	~	nc

nd = non-detect, nc = not calculated

Shaded cells are one-half the method detection limit.

Table 9. PCBs and DDT in **RECONSTRUCTED WHOLEBODY BULLHEAD** from the Nashua River, *u* g/g WW.

Sample No.	Aroclor 1248	Aroclor 1254	Aroclor 1260	Total PCB	o,p' DDD	p,p' DDD	p,p' DDE	p,p' DDT	Total DDT
SDP1-BBH-5C	0.26	0.18	0.10	0.54	nd	0.044	0.036	nd	0.080
SDP1-YBH-6C	0.10	0.11	0.08	0.29	nd	0.013	0.014	nd	0.027
SA11-YBH-6C	0.16	0.09	0.15	0.40	nd	0.027	0.020	0.011	0.058
SA10-BBH-1	0.32	0.18	0.10	0.60	0.009	0.043	0.015	nd	0.067
SA10-BBH-2	0.29	0.18	0.08	0.55	0.008	0.074	0.055	nd	0.137
SA10-BBH-3	0.10	0.19	0.06	0.35	nd	0.020	0.015	nd	0.034
n=6									
Arithmetic Mean*	0.20	0.15	0.10	0.46	nc	0.037	0.026	nc	0.067

* The mean should be considered an estimate because some samples were composites.
Sample numbers ending in "C" indicate a composite.
nd = non-detect, nc = not calculated

Table 10. PCBs and DDT in **WHOLEBODY** samples of **PERCH** from the Nashua River, *u* g/g WW.

Sample No.	Aroclor 1248	Aroclor 1254	Aroclor 1260	Total PCB	o,p' DDD	o,p' DDE	o,p' DDT	p,p' DDD	p,p' DDE	p,p' DDT	Total DDT
SDP1-YwP-4	1.80	0.97	0.51	3.28	0.031	nd	nd	0.290	0.140	0.011	0.472
SDP1-YwP-6C	1.80	0.97	0.50	3.27	0.026	nd	nd	0.260	0.150	0.013	0.449
SDP1-YwP-7C	0.86	0.54	0.29	1.69	0.013	nd	nd	0.140	0.095	0.018	0.266
SA11-YwP-1	0.85	0.52	0.36	1.73	0.010	nd	0.030	0.140	0.090	0.150	0.420
SA11-YwP-6C	0.84	0.45	0.23	1.52	0.016	nd	nd	0.130	0.079	0.038	0.263
SA11-YwP-7C	1.30	0.73	0.35	2.38	0.027	nd	0.014	0.180	0.110	0.029	0.360
SA10-YwP-1	1.80	0.44	0.35	2.59	0.039	0.010	nd	0.460	0.160	0.028	0.697
SA10-YwP-6C	1.30	0.92	0.55	2.77	0.026	nd	nd	0.270	0.160	0.120	0.576
SA10-YwP-7C	1.10	0.54	0.26	1.90	0.037	nd	nd	0.330	0.170	0.100	0.637
n=9											
Arithmetic Mean*	1.29	0.68	0.38	2.35	0.03	nc	nc	0.24	0.13	0.06	0.46

* The mean should be considered an estimate because some samples were composites.
Sample numbers ending in "C" indicate a composite.
nd = non-detect, nc = not calculated

Table 11. Chlordane compounds and dieldrin in **FILLET** samples of **BASS** from the Nashua River, *u* g/g WW.

Fish No.	*alpha* chlordane	*cis* nonachlor	*gamma* chlordane	oxy chlordane	*trans* nonachlor	Dieldrin
SDP1-LmB-1	nd	nd	nd	nd	nd	nd
SDP1-LmB-2	0.013	nd	nd	nd	nd	nd
SDP1-LmB-3	nd	nd	nd	nd	nd	nd
SDP1-LmB-4	nd	nd	nd	nd	nd	nd
SDP1-LmB-5	nd	nd	nd	nd	nd	nd
SA11-LmB-1	nd	nd	nd	nd	nd	nd
SA11-LmB-2	nd	nd	nd	nd	nd	nd
SA11-LmB-3	nd	nd	nd	nd	nd	nd
SA11-LmB-4	nd	nd	nd	nd	nd	nd
SA11-LmB-5	nd	nd	nd	nd	nd	nd
SA10-LmB-1	nd	nd	nd	nd	nd	nd
SA10-LmB-2	nd	nd	nd	nd	nd	nd
SA10-LmB-3	nd	nd	nd	nd	nd	nd
SA10-LmB-4	nd	nd	nd	nd	nd	nd
SA10-LmB-5	nd	nd	nd	nd	nd	nd
SA10-LmB-6	nd	nd	nd	nd	nd	nd
n=16						
Geometric Mean	nc	nd	nd	nd	nd	nd
SE	~	~	~	~	~	~

nd = non-detect

Table 12. Chlordane compounds and dieldrin in **RECONSTRUCTED WHOLEBODY BASS** from the Nashua River, *u* g/g WW.

Sampe No.	*alpha* chlordane	*cis* nonachlor	*gamma* chlordane	oxy chlordane	*trans* nonachlor	Total Chlordane	Dieldrin
SDP1-LmB-6C	0.012	nd	nd	nd	0.015	0.027	nd
SDP1-LmB-7C	0.023	0.009	nd	nd	0.021	0.054	nd
SA11-LmB-1	0.017	nd	nd	nd	0.015	0.032	nd
SA11-LmB-6C	nd	nd	nd	nd	0.009	0.010	nd
SA11-LmB-7C	0.008	nd	nd	nd	0.008	0.017	0.01
SA10-LmB-1	0.009	nd	nd	nd	nd	0.010	nd
SA10-LmB-3	nd	nd	nd	nd	nd	0.005	nd
SA10-LmB-7C	nd	nd	nd	nd	nd	0.005	nd
SA10-LmB-8C	0.012	0.010	nd	nd	0.015	0.037	nd
n=9							
Arithmetic Mean*	nc	nc	nd	nd	nc	0.022	nc

* The mean should be considered an estimate because some samples were composites.
Sample numbers ending in "C" indicate a composite.

nd = non-detect, nc = not calculated

Total Chlordane is the sum of *alpha* -chlordane, *cis* -nonachlor, *gamma* -chlordane, oxychlordane, and *trans* -nonachlor

Shaded values are one-half the detection limit.

Table 13. Chlordane compounds and dieldrin in **FILLET** samples of **BULLHEAD** from the Nashua River, *u* g/g WW.

Fish No.	*alpha* chlordane	*cis* nonachlor	*gamma* chlordane	oxy chlordane	*trans* nonachlor	Dieldrin
SDP1-BBH-1F	nd	nd	nd	nd	nd	nd
SDP1-BBH-2F	nd	nd	nd	nd	nd	nd
SDP1-YBH-3F	nd	nd	nd	nd	nd	nd
SDP1-YBH-4F	nd	nd	nd	nd	nd	nd
SA11-YBH-1F	nd	nd	nd	nd	nd	nd
SA11-YBH-2F	nd	nd	nd	nd	nd	nd
SA11-YBH-3F	nd	nd	nd	nd	nd	nd
SA11-YBH-4F	nd	nd	nd	nd	nd	nd
SA11-YBH-5F	nd	nd	nd	nd	nd	nd
SA10-BBH-1F	nd	nd	nd	nd	nd	nd
SA10-BBH-2F	nd	nd	nd	nd	nd	nd
SA10-BBH-3F	nd	nd	nd	nd	nd	nd
n=12						
Geometric Mean	nd	nd	nd	nd	nd	nd
SE	~	~	~	~	~	~

nd = non-detect

Table 14. Chlordane compounds and dieldrin in **RECONSTRUCTED WHOLEBODY BULLHEAD** from the Nashua River, *u* g/g WW.

Sample No.	*alpha* chlordane	*cis* nonachlor	*gamma* chlordane	oxy chlordane	*trans* nonachlor	Dieldrin
SDP1-BBH-5C	0.0126	nd	nd	nd	nd	nd
SDP1-YBH-6C	nd	nd	nd	nd	nd	nd
SA11-YBH-6C	nd	nd	nd	nd	nd	nd
SA10-BBH-1	nd	nd	nd	nd	nd	nd
SA10-BBH-2	nd	nd	nd	nd	nd	nd
SA10-BBH-3	nd	nd	nd	nd	nd	nd
n=6						
Arithmetic Mean	nc	nd	nd	nd	nd	nd

Sample numbers ending in "C" indicate a composite
nd = non-detect

Table 15. Chlordane compounds and dieldrin in **WHOLEBODY** samples of **PERCH** from the Nashua River, *u* g/g WW.

Sample No.	*alpha* chlordane	*cis* nonachlor	*gamma* chlordane	oxy chlordane	*trans* nonachlor	Total Chlordane	Dieldrin
SDP1-YwP-4	0.060	0.024	nd	0.013	0.054	0.151	0.015
SDP1-YwP-6C	0.054	0.023	0.010	0.014	0.052	0.153	0.015
SDP1-YwP-7C	0.029	0.012	nd	nd	0.026	0.067	0.005
SA11-YwP-1	0.041	0.017	nd	0.011	0.041	0.110	0.010
SA11-YwP-6C	0.022	nd	nd	nd	0.020	0.042	0.010
SA11-YwP-7C	0.036	0.014	0.010	0.010	0.031	0.101	0.012
SA10-YwP-1	0.017	0.010	nd	nd	0.013	0.040	0.016
SA10-YwP-6C	0.034	0.019	nd	0.012	0.048	0.113	0.011
SA10-YwP-7C	0.024	nd	nd	nd	0.021	0.045	0.012
n=9							
Arithmetic Mean*	0.03	nc	nc	nc	0.03	0.091	0.01

* The mean should be considered an estimate because some samples were composites.
Sample numbers ending in "C" indicate a composite.

nd = non-detect, nc = not calculated

Total chlordane is the sum of *alpha* -chlordane, *cis* -nonachlor, *gamma* -chlordane, oxychlordane, and *trans* -nonachlor.

Shaded cell was a non-detect. One-half the method detection limit was used in the calculation of the mean.

Table 16. Trace elements in **FILLET** samples of **BASS** from the Nashua River, *u* g/g WW.

Fish No.	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
SDP1-LmB-1F	nd	nd	nd	0.85	0.44	nd	nd	0.64	9.14
SDP1-LmB-2F	nd	nd	nd	0.17	0.44	nd	nd	0.78	5.67
SDP1-LmB-3F	nd	nd	nd	0.26	0.47	nd	nd	0.55	6.61
SDP1-LmB-4F	0.11	nd	nd	0.23	0.34	nd	nd	0.44	5.73
SDP1-LmB-5F	0.21	nd	nd	0.34	0.22	nd	nd	0.71	6.01
SA11-LmB-1F	nd	nd	nd	0.40	0.61	nd	nd	0.40	3.79
SA11-LmB-2F	nd	nd	nd	0.35	0.30	nd	nd	0.52	5.74
SA11-LmB-3F	nd	nd	nd	0.46	0.23	nd	nd	0.60	7.04
SA11-LmB-4F	nd	nd	nd	0.36	0.24	nd	nd	0.49	7.62
SA11-LmB-5F	nd	nd	nd	0.27	0.24	nd	nd	0.51	5.71
SA10-LmB-1F	nd	nd	nd	0.51	0.35	nd	nd	0.49	5.26
SA10-LmB-2F	nd	nd	nd	0.21	0.33	nd	nd	0.39	5.64
SA10-LmB-3F	nd	nd	nd	0.48	0.21	nd	nd	0.53	9.34
SA10-LmB-4F	nd	nd	nd	0.22	0.61	nd	nd	0.49	6.28
SA10-LmB-5F	nd	nd	nd	0.51	0.33	nd	nd	0.69	6.06
SA10-LmB-6F	nd	nd	nd	0.25	0.24	nd	nd	0.87	6.29
n=16									
Geometric Mean	nc	nd	nd	0.34	0.33	nd	nd	0.56	6.23
SE	nc	~	~	0.043	0.033	~	~	0.034	0.347

nd = non-detect, nc = not calculated

Table 17. Trace elements in **RECONSTRUCTED WHOLEBODY BASS** from the Nashua River, *u* g/g WW

Sample No.	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
SDP1-LmB-6C	0.61	0.04	0.95	0.86	0.18	nd	nd	0.43	23.32
SDP1-LmB-7C	0.49	0.06	0.99	0.81	0.26	nd	nd	0.55	14.25
SA11-LmB-1	0.64	0.06	0.52	1.77	0.46	nd	nd	0.49	17.05
SA11-LmB-6C	0.32	0.09	0.58	1.24	0.18	nd	0.29	0.47	21.51
SA11-LmB-7C	0.26	0.08	0.58	1.00	0.16	nd	0.30	0.56	20.73
SA10-LmB-1	0.14	0.09	0.69	1.20	0.24	nd	nd	0.51	22.97
SA10-LmB-3	0.27	0.11	0.83	1.82	0.15	nd	0.45	0.64	24.15
SA10-LmB-7C	0.34	0.06	0.63	0.61	0.23	nd	nd	0.69	20.28
SA10-LmB-8C	0.93	0.08	0.55	0.56	0.30	nd	nd	0.48	19.54
n=9									
Arithmetic Mean*	0.45	0.08	0.70	1.10	0.24	nd	nc	0.54	20.42

* The mean should be considered an estimate because some samples are composites.
Sample numbers ending in a "C" indicate a composite.
nd = non-detect, nc = not calculated

Table 18. Trace elements in **FILLET** samples of **BULLHEAD** from the Nashua River, *u* g/g WW.

Fish No.	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
SDP1-BBH-1F	nd	nd	nd	0.24	0.08	nd	nd	0.27	4.14
SDP1-BBH-2F	0.35	nd	nd	0.41	0.08	nd	nd	0.42	7.40
SDP1-YBH-3F	nd	nd	nd	0.66	0.55	nd	nd	0.42	10.84
SDP1-YBH-4F	nd	nd	nd	0.30	0.42	nd	nd	0.37	7.32
SA11-YBH-1F	nd	nd	nd	0.47	0.45	nd	nd	0.26	4.99
SA11-YBH-2F	nd	nd	nd	0.37	0.46	nd	nd	0.26	7.45
SA11-YBH-3F	nd	0.02	nd	0.45	0.37	nd	nd	0.31	9.55
SA11-YBH-4F	nd	0.02	nd	0.34	0.41	nd	nd	0.28	6.20
SA11-YBH-5F	nd	0.02	nd	0.56	0.41	nd	nd	0.31	9.42
SA10-BBH-1F	nd	nd	nd	0.36	0.07	nd	nd	0.24	8.36
SA10-BBH-2F	nd	nd	nd	0.32	0.11	nd	nd	0.20	7.83
SA10-BBH-3F	nd	nd	nd	0.27	0.69	nd	nd	0.27	9.24
n=12									
Geometric Mean	nc	nc	nd	0.38	0.26	nd	nd	0.29	7.48
SE	nc	nc	~	0.035	0.059	~	~	0.020	0.562

nd = non-detect, nc = not calculated

Table 19. Trace elements in **RECONSTRUCTED WHOLEBODY BULLHEAD** from the Nashua River, *u* g/g WW.

Sample No.	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
SDP1-BBH-5C	0.81	0.16	1.76	1.02	0.06	0.18	0.89	0.64	34.93
SDP1-YBH-6C	0.30	0.23	0.50	0.57	0.38	nd	0.15	0.47	19.98
SA11-YBH-6C	0.16	0.12	0.72	0.69	0.18	nd	0.41	0.34	23.14
SA10-BBH-1	0.23	0.15	0.95	1.21	0.05	0.19	1.11	0.53	22.10
SA10-BBH-2	0.11	0.03	0.44	0.51	0.07	0.11	0.33	0.29	19.61
SA10-BBH-3	0.33	0.23	0.57	1.93	0.49	nd	0.63	0.39	20.59
n=6									
Arithmetic Mean*	0.32	0.15	0.82	0.99	0.20	nc	0.59	0.44	23.39

* The mean should be considered an estimate because some samples are composites.
Sample numbers ending in "C" indicate a composite.

nd = non-detect, nc = not calculated

Shaded cell was a non-detect. Value listed is one-half the sample detection limit.

Table 20. Trace elements in **WHOLEBODY** samples of **PERCH** from the Nashua River, *u* g/g WW.

Fish No.	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
SDP1-YwP-4	0.47	0.10	44.63	0.76	0.06	0.65	1.52	1.20	22.21
SDP1-YwP-6C	0.25	0.09	16.55	0.75	0.09	0.35	1.55	1.13	23.82
SDP1-YwP-7C	0.95	0.11	1.50	1.04	0.21	0.08	1.11	0.88	20.02
SA11-YwP-1	0.21	0.09	29.86	1.17	0.19	0.46	0.59	0.88	18.09
SA11-YwP-6C	0.86	0.10	1.31	1.15	0.16	0.07	0.74	0.54	25.65
SA11-YwP-7C	0.49	0.09	16.69	0.87	0.11	0.41	0.90	0.81	30.66
SA10-YwP-1	0.48	0.08	5.80	0.57	0.12	0.09	1.17	0.84	20.67
SA10-YwP-6C	0.19	0.16	0.89	1.91	0.27	0.08	1.39	0.75	22.96
SA10-YwP-7C	0.19	0.14	4.40	1.15	0.19	0.17	0.57	0.68	17.98
n=9									
Arithmetic Mean*	0.45	0.11	13.51	1.04	0.16	0.26	1.06	0.86	22.45

* The mean should be considered an estimate because some samples are composites.
Sample numbers ending in "C" indicate a composite.
Shaded cells represent non-detects. Value listed is one-half the sample detection limit.

APPENDIX A

ECDMS ANALYTICAL REPORT - ORGANOCHLORINES
MISSISSIPPI STATE CHEMICAL LABORATORY

APPENDIX B

ECDMS ANALYTICAL REPORT - TRACE ELEMENTS
RESEARCH TRIANGLE INSTITUTE